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THE USE OF ADAP TO EXAMINE WARM AND QUASI-STATIONARY FRONTAL EVENTS IN THE NORTHEASTERN UNITED STATES

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1. INTRODUCTION

The suite of AFOS Data Analysis Programs, called ADAP (Bothwell 1988), is an outstanding mesoanalysis tool for the detection and prediction of convection and severe weather development. Many offices now utilize ADAP on a routine basis. With increased usage, it is becoming more apparent that ADAP can also be extremely helpful during non-convective weather situations.

Peleski (1988) showed how ADAP assisted forecasters in the analysis of a cold frontal passage through Delaware. For this event, ADAP output, particularly the surface theta advection chart (AFOS graphic STA), alerted the forecasters to the relatively weak cold air advection behind the primary cold front, giving them the opportunity to raise the predicted high temperatures. ADAP also detected the development of a secondary cold front, behind which most of the cold air advection was located. In another case, Hitchens (1990) illustrated how ADAP assisted forecasters during a winter weather event in the mid-Atlantic states. In this case where the dynamical model forecasts were of limited value, ADAP analyses of cold and warm advection centers proved to be a valuable tool in determining where and when a changeover in precipitation type would occur.

This paper will examine ADAP output from several warm and quasi-stationary frontal events over the Northeast during the spring through the early winter of 1990. I will show how ADAP can assist the forecaster in the detection and movement of warm and quasi-stationary fronts. The limitations of the ADAP output during such events also will be discussed.

2. BACKGROUND

The usefulness of most analysis programs, especially those that involve mesoscale analysis, are highly dependent upon the availability and reliability of data. In the Northeast, the data coverage is quite good. Spacing between stations is small in comparison to parts of the Rocky Mountain West, for example. Figure 1 shows the surface and upper air stations that are used for operation of the ADAP program at the Weather Service Office (WSO) in Providence, RI (PVD).

Two problems are inherent to the ADAP program in the Northeast. First, several stations throughout the region do not operate twenty-four hours a day. The data from these stations are typically unavailable for the analyses between 0400 and 1000 UTC. Second, ADAP requires that all stations used in the analysis report certain variables, among which is dew point. This precludes the inclusion of coast guard and buoy observations in the analysis. Therefore, with the exception of immediate coastal stations, there are no available data over the waters of the Atlantic Ocean along the Middle and Northeast Atlantic coasts. In addition, some of the immediate coastal stations are part-time stations. The ADAP grid at WSO PVD was set up to maximize data coverage and availability, and for the most part, the program does an excellent job in properly detecting maritime influences like sea breezes and the coastal front. There are times, however, especially when data are missing or incorrectly formatted, that a large data void exists, which the analyses will still attempt to account for. Forecasters must be mindful of this when examining the data along the coast, or whenever suspicious results show up in an analysis. Additionally, ADAP, like any analysis tool, should be used in concert with other data sources like satellite imagery, radar information, etc. These particular problems, and their impact on the ADAP output, will be discussed in more detail later.

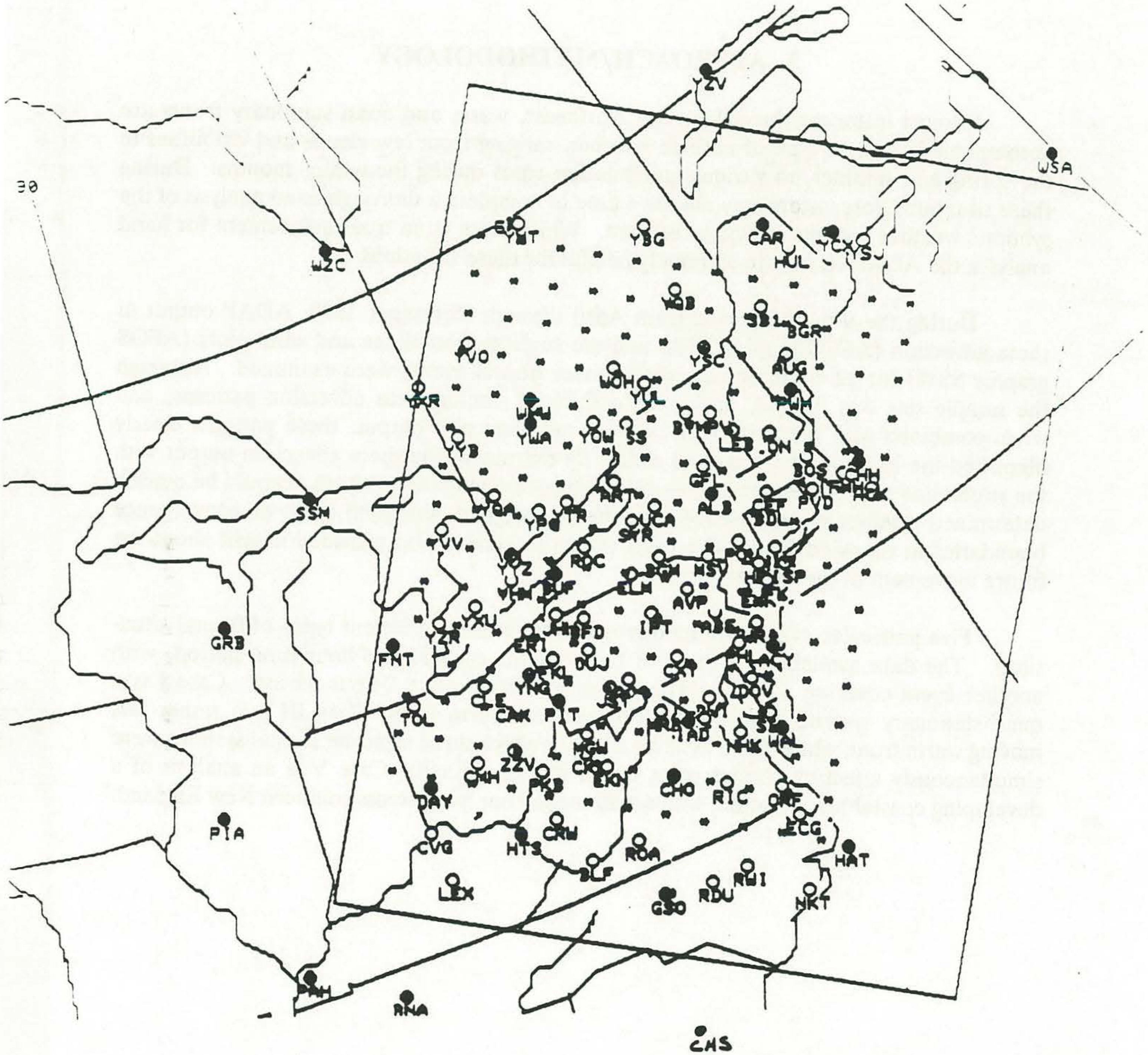

Figure 1. Analysis grid used in the ADAP program at WSO Providence. Open circles indicate surface observations included in the analysis. Closed circles indicate both soundings and surface observations are used.

3. APPROACH/METHODOLOGY

In most instances throughout the Northeast, warm and quasi-stationary fronts are accompanied by some type of adverse weather, ranging from low clouds and visibilities in the spring and summer, to various precipitation types during the winter months. During these situations, forecasters may not have time to complete a thorough hand analysis of the synoptic weather systems affecting the area. While there is no true replacement for hand analysis, the ADAP charts are extremely helpful for these situations.

During the 9-month period from April through December 1990, ADAP output of theta advection (AFOS graphic STA) and the surface streamlines and wind plots (AFOS graphic SSW) for 12 warm and quasi-stationary frontal events were examined. Although the sample size was limited, each event exhibited similar theta advection patterns, and when combined with the surface streamline and wind plot output, these patterns clearly identified the location of the frontal zone. By examining the theta advection output with the streamline analysis, either side-by-side or by overlaying the analyses, it could be quickly determined whether or not the frontal zone was aligned with wind shifts or convergence boundaries in the wind field. The theta advection output also provided insight about the future movement of the frontal zone.

Five particular events will be discussed that present different types of frontal situations. The data available for three of these events covered a 6-hour time period, with another event covering 8 hours. The last case only covers a 2-hour period. Case I is a quasi-stationary system; Case II is a slow moving warm front; Case III is a rather fast moving warm front, while Case IV is an event in which three separate frontal systems were simultaneously affecting various parts of the region. Finally, Case V is an analysis of a developing coastal low situation, with a stationary front lying across southern New England.

4. CASE STUDIES

4.1. CASE I - WARM/QUASI-STATIONARY FRONT

Low pressure was developing in the vicinity of the central Great Lakes at 1100 UTC, May 20, 1990. A quasi-stationary front extended from Lake Erie, southward across western Pennsylvania and Maryland, and eastward to the middle Atlantic coast as depicted in Figure 2. The surface theta advection chart for 1100 UTC (Figure 3) provided a first approximation for the frontal location. Positive values represent areas of warm advection, while negative values denote cold advection. Centers (relative maxima) of the advection areas are denoted by a W or a C for warm or cold advection, respectively. The frontal zone was located along the leading edge of the gradient of warm advection. The streamlines and wind plot graphic at 1100 UTC further supported this location by the distinct shifts in wind direction (Figure 4). (Marked wind shifts and convergence in the streamline pattern, when present in the analyses, offer a quick and accurate identification of the frontal trough.) The theta advection pattern was aligned with the wind shift/convergence boundary in the streamline analysis, giving an excellent indication of frontal position. This is also a feature that could be easily followed over time.

Not all frontal positions will align themselves in a clear and straightforward manner. It is important to keep in mind that, as Doswell (1982) stated, a front designates a three-dimensional zone where atmospheric density varies substantially; it is not a true discontinuity, and its width may vary significantly. This particular case revealed a rather narrow frontal zone, easily identified by the tight theta advection gradient which did correspond with convergence in the wind field.

At 1100 UTC, two advection centers are apparent; a warm center in northeast Ohio and a cold center, indicative of cold air damming, over eastern Pennsylvania (Figure 3). By 1300 UTC, the leading edge of the warm advection had pushed into southwest New York, indicating that some eastward movement of the front had occurred (Figure 5). The cold center remained nearly stationary across eastern Pennsylvania and New Jersey. The SSW graphic (Figure 6) helped confirm this analysis.

The ADAP output also allowed for the real time examination of cold air damming. The persistence and strength of the cold air damming signature over eastern Pennsylvania indicated that any northward movement of the boundary across the middle Atlantic coast would be minimal during the next few hours. In addition, the extension of the cold advection northward toward Lake Ontario suggested that eastward progression of the warm front across western New York would be slow to occur.

During the next 2 hours, the ADAP patterns remained basically the same. The northwest portion of the frontal surface continued to move very slowly northeastward toward southern Ontario. Meanwhile, the southern half of the frontal surface remained nearly stationary, as indicated by the 1500 UTC STA and SSW output (Figures 7 and 8). This is further supported by the local surface analysis (Figure 9).

One notable feature did begin appear, however, in the vicinity of Elmira (ELM) and Binghamton (BGM), New York. An area of weak warm advection, ahead of the frontal zone, was developing in this area. At first glance, the surface observations shown in Figure 9 appear to be suspicious, since ELM is reporting a temperature of 57°F, while BGM is only 49°F. However, the station elevation of BGM is 700 feet higher than ELM, so a colder surface temperature would be expected. Since we are examining the advection of potential temperature, temperature biases caused by station elevation are, for the most part, eliminated. To confirm that this temperature difference is primarily a function of station elevation, we compared the 4-hour temperature changes from 1100 to 1500 UTC (Figures 2 and 9) at the two stations. The temperature at ELM increased 7°F, while BGM showed a similar increase of 5°F. Therefore, this weak area of warm advection was likely real. This new area of warm advection could be a signature of future frontal movement. The warm center indicated that the cold advection which was present in the area earlier, was eroding. If this area of warm advection continued to persist and strengthen on subsequent analyses, then it might be of use for the preparation of short- range forecasts of frontal position.

At 1700 UTC, the theta advection analysis (Figure 10) showed that the western portion of the frontal zone had pushed eastward along the New York-Pennsylvania border, as was suggested by the 1500 UTC analysis. The streamline output (Figure 11) revealed a slight veering in the wind field over this area (Figure 11). The surface observations across western New York and western Pennsylvania further supported this analysis through rises in dew point in addition to the veering of the surface winds (Figure 12). Notice how the area of warm advection ahead of the front (Figure 10) persisted and strengthened, indicating additional eastward acceleration of the front was likely across south central New York.

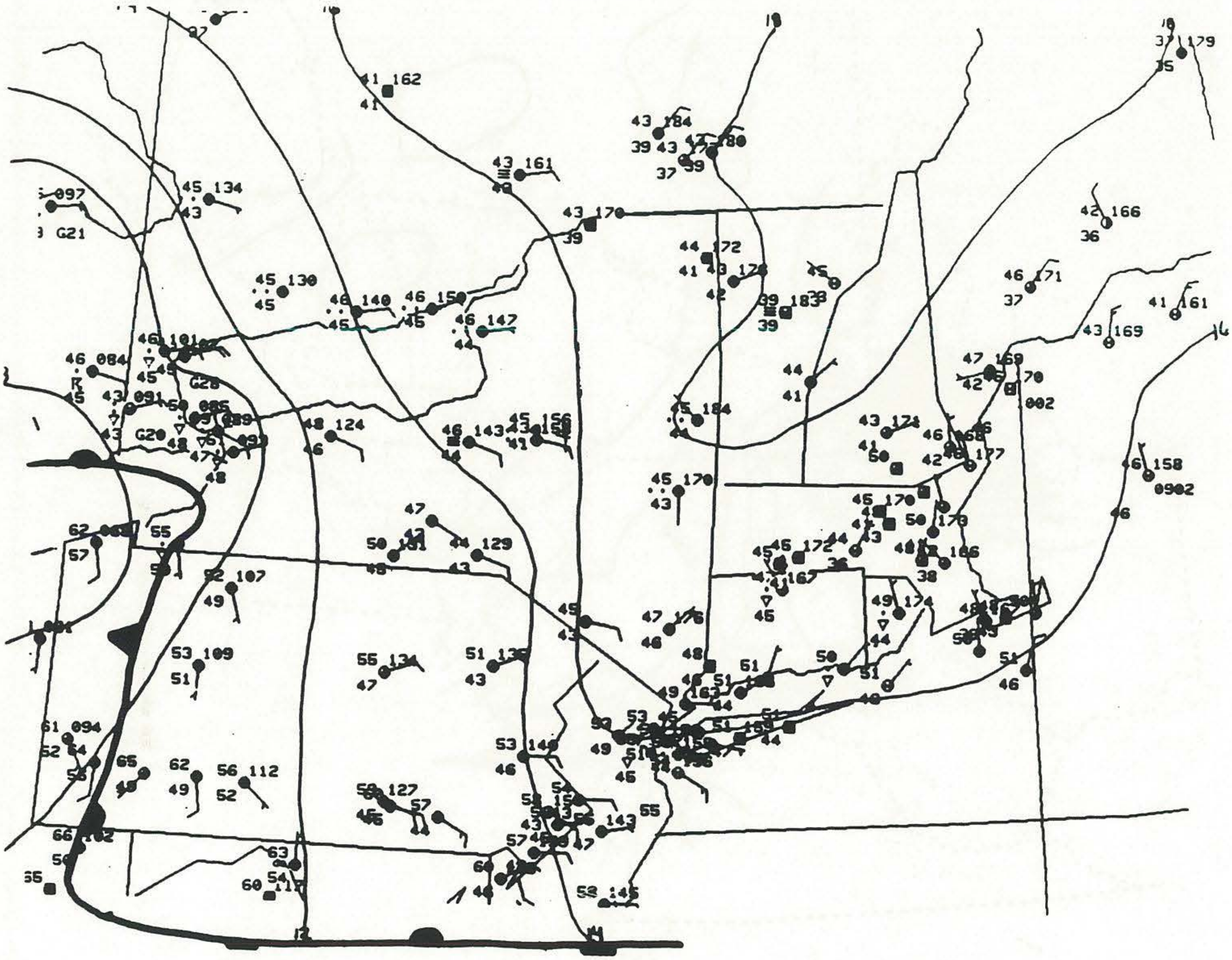

Figure 2. Surface plot and analysis for 1100 UTC, May 20, 1990.

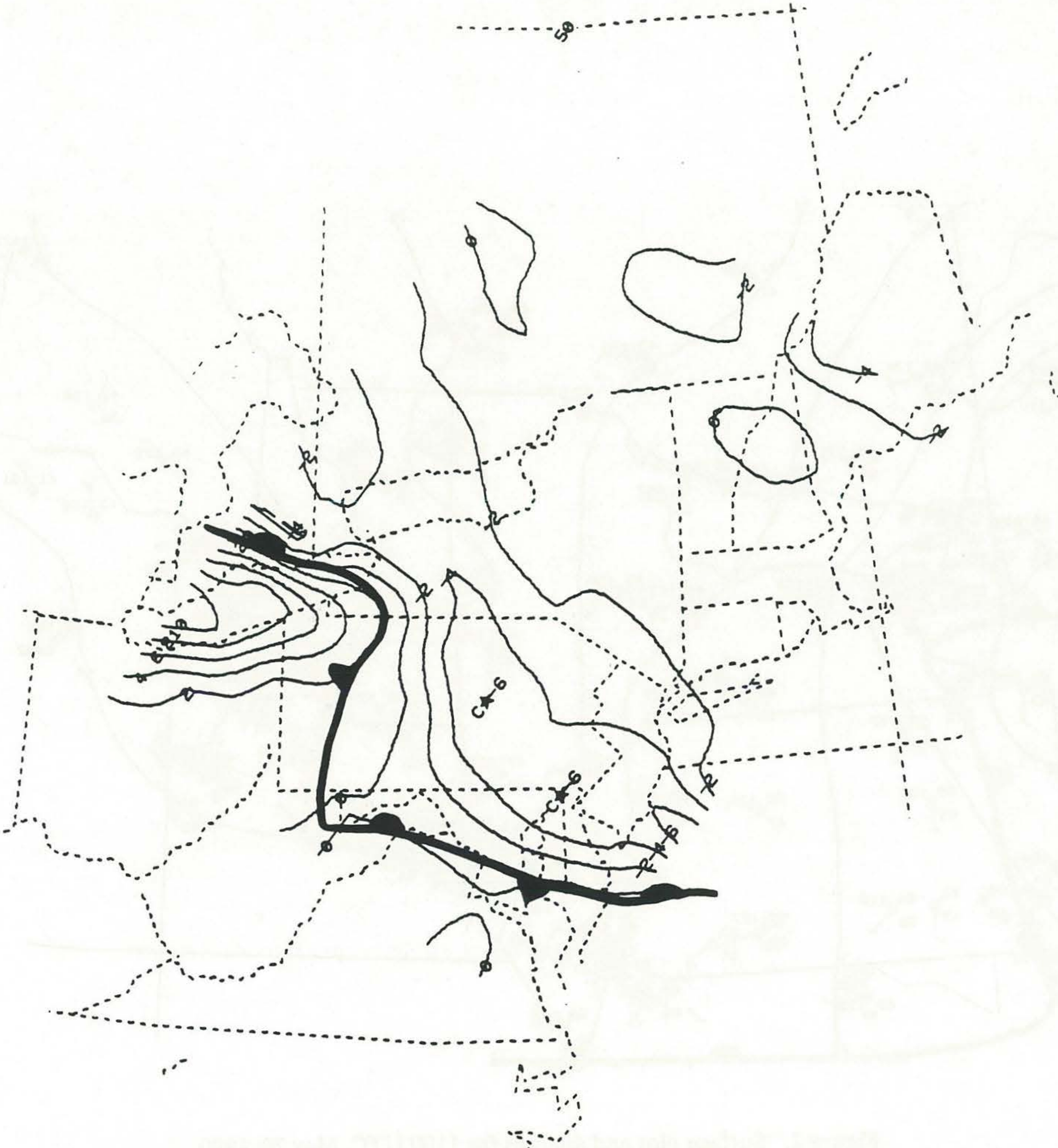

Figure 3. Surface theta advection (°F hr^{-1}*10) for 1100 UTC, May 20, 1990.

Figure 4. Surface streamlines/wind plot (standard wind barbs) for 1100 UTC, May 20, 1990.

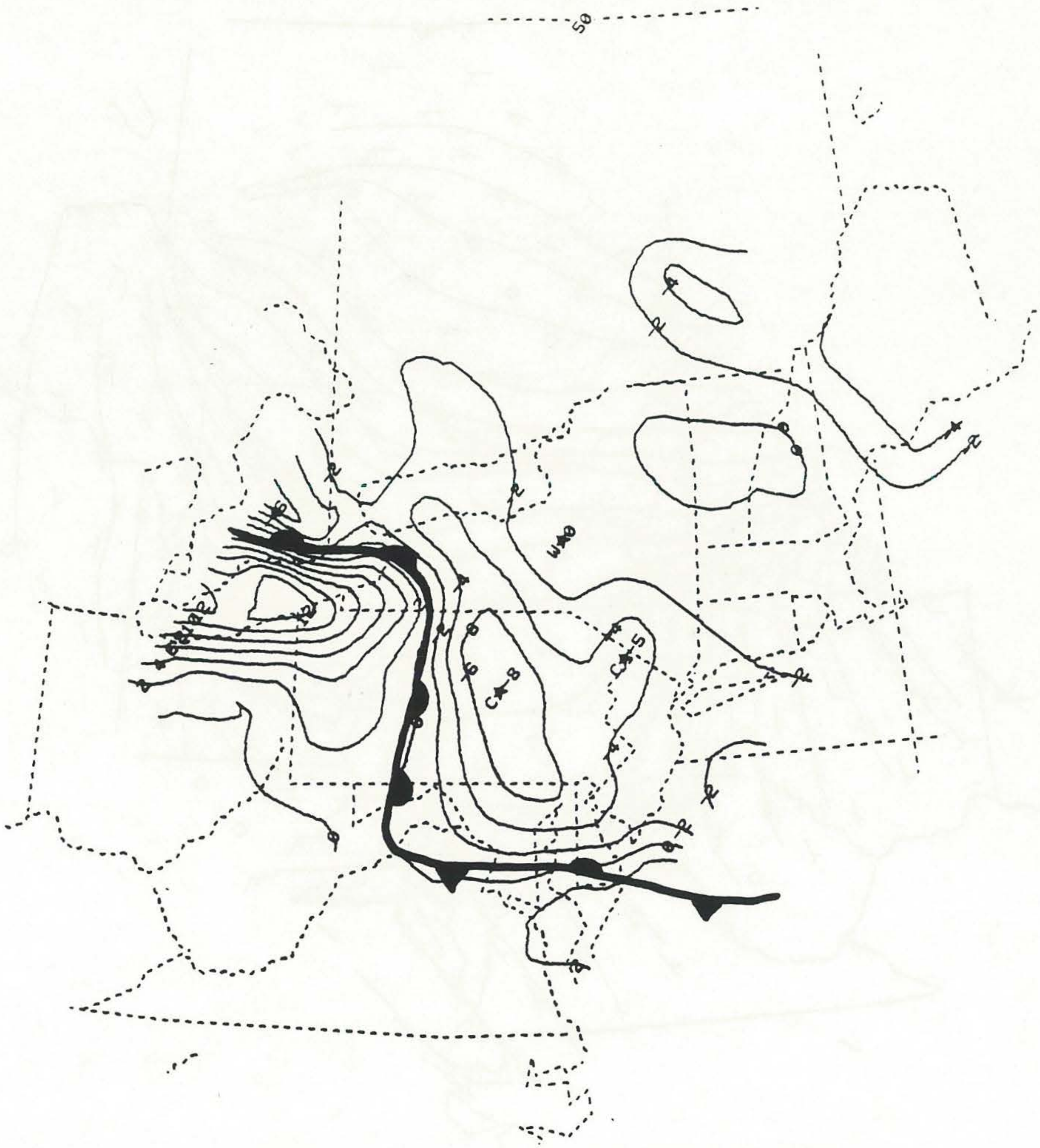

Figure 5. Surface theta advection for 1300 UTC, May 20, 1990.

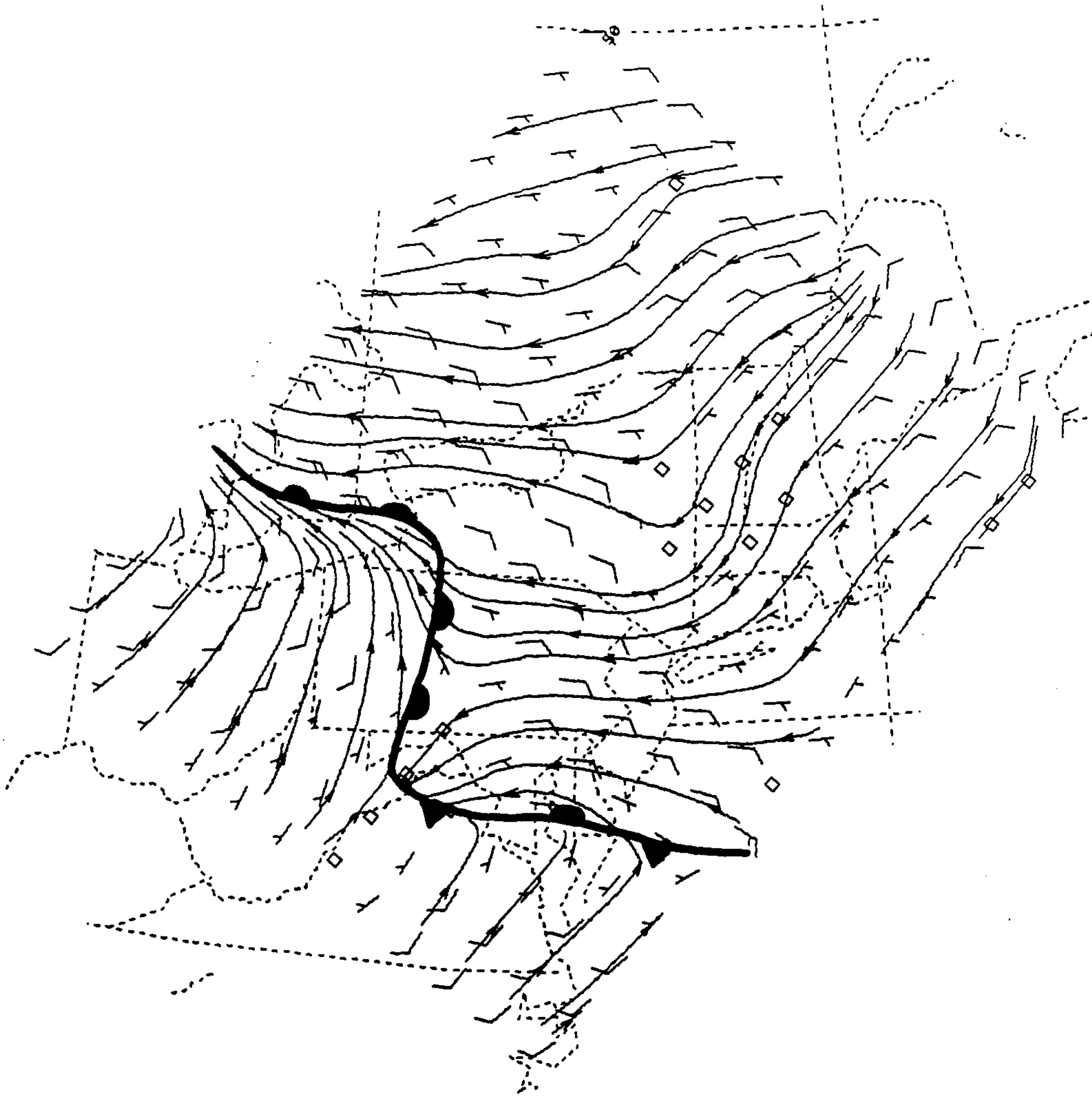

Figure 6. Surface streamlines/wind plot for 1300 UTC, May 20, 1990.

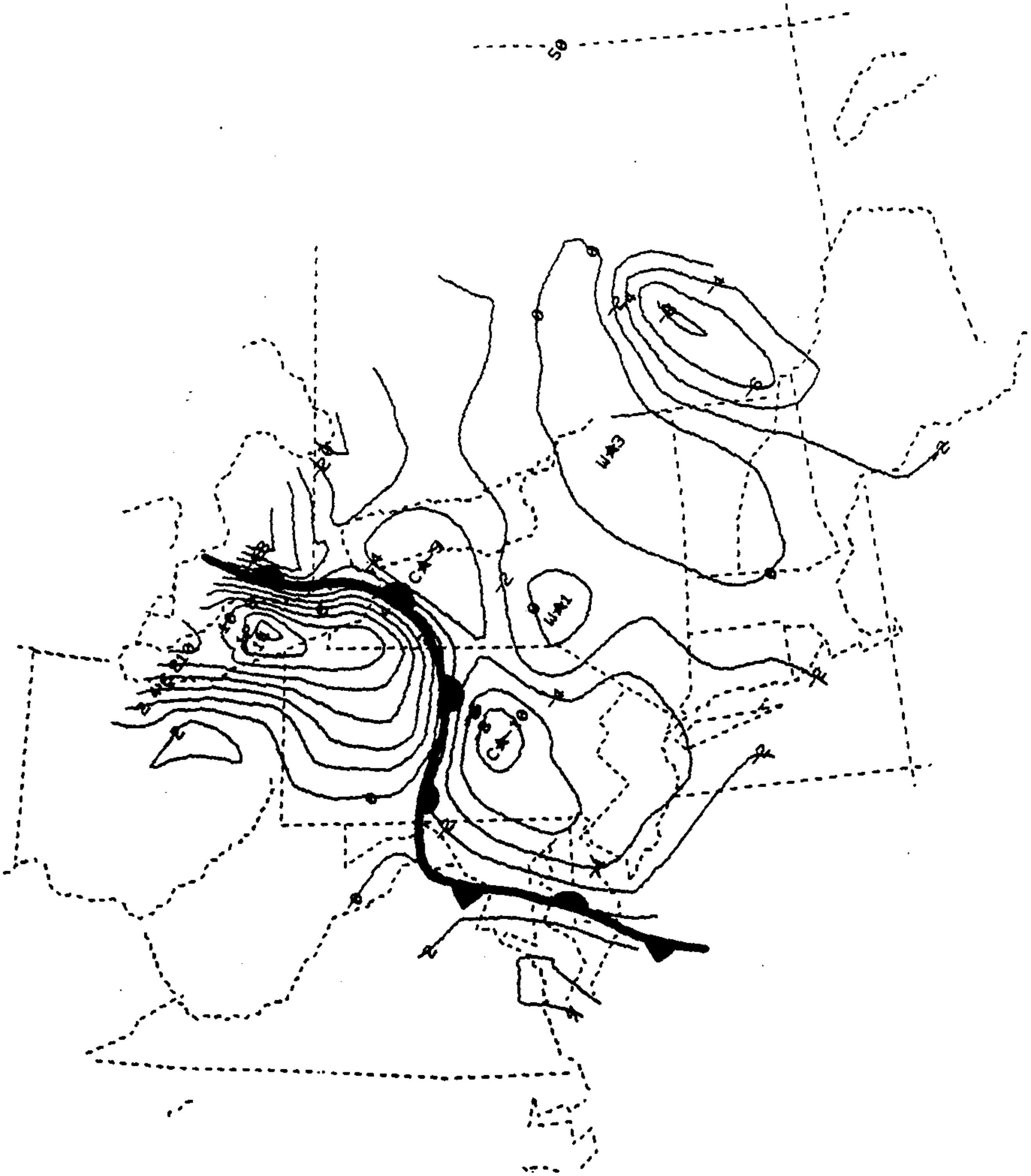

Figure 7. Surface theta advection for 1500 UTC, May 20, 1990.

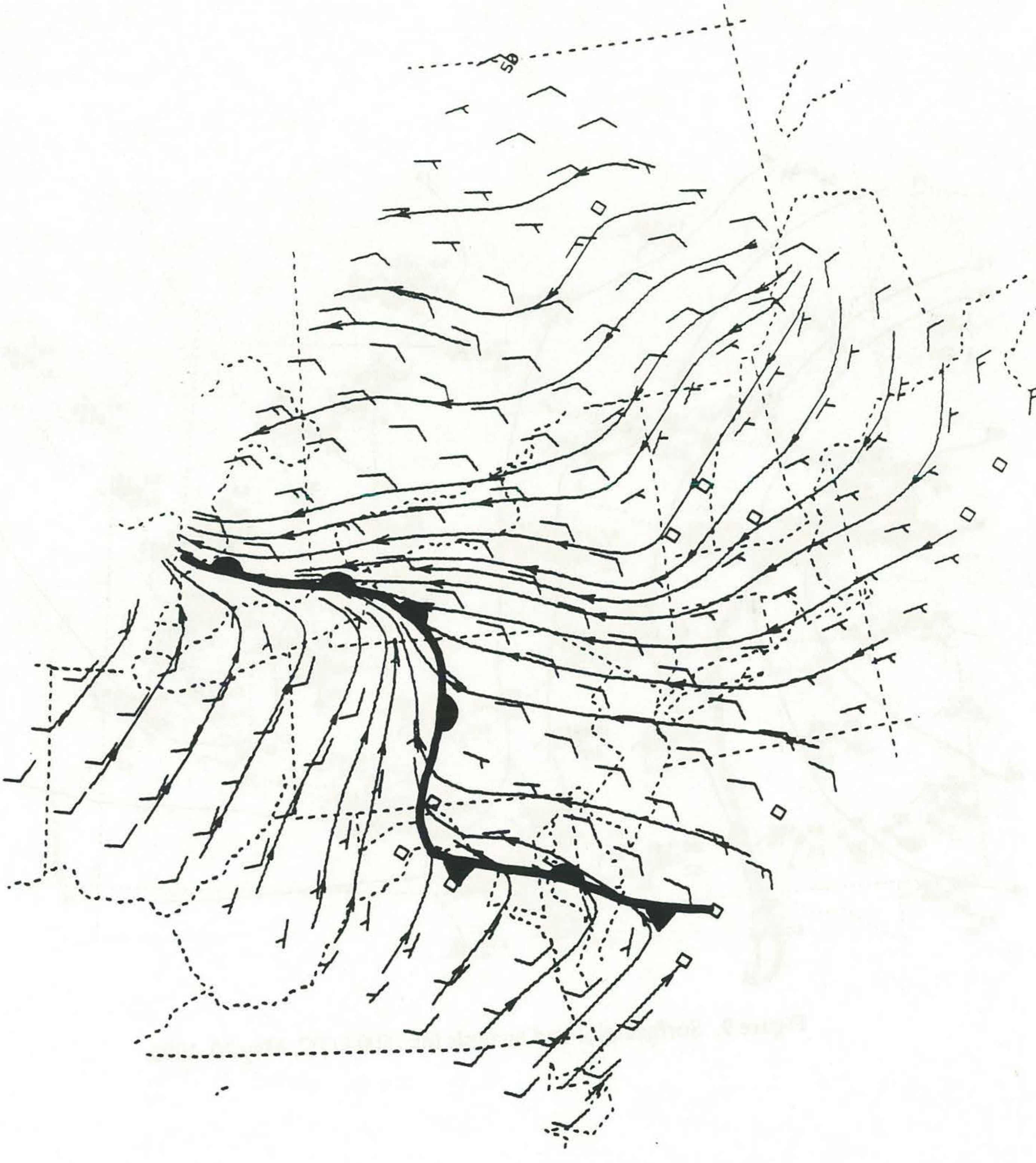

Figure 8. Surface streamlines/wind plot for 1500 UTC, May 20, 1990.

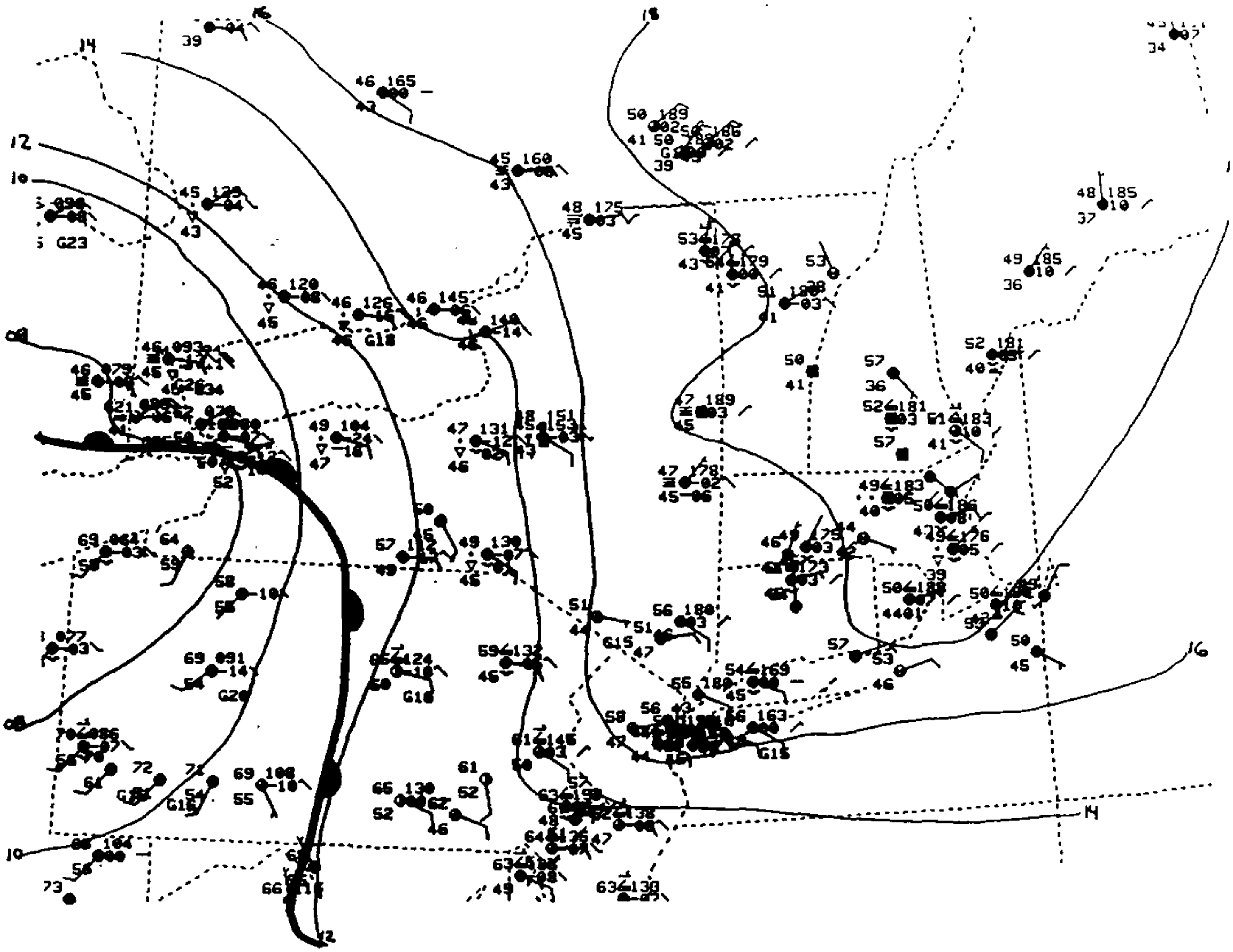

Figure 9. Surface plot and analysis for 1500 UTC, May 20, 1990.

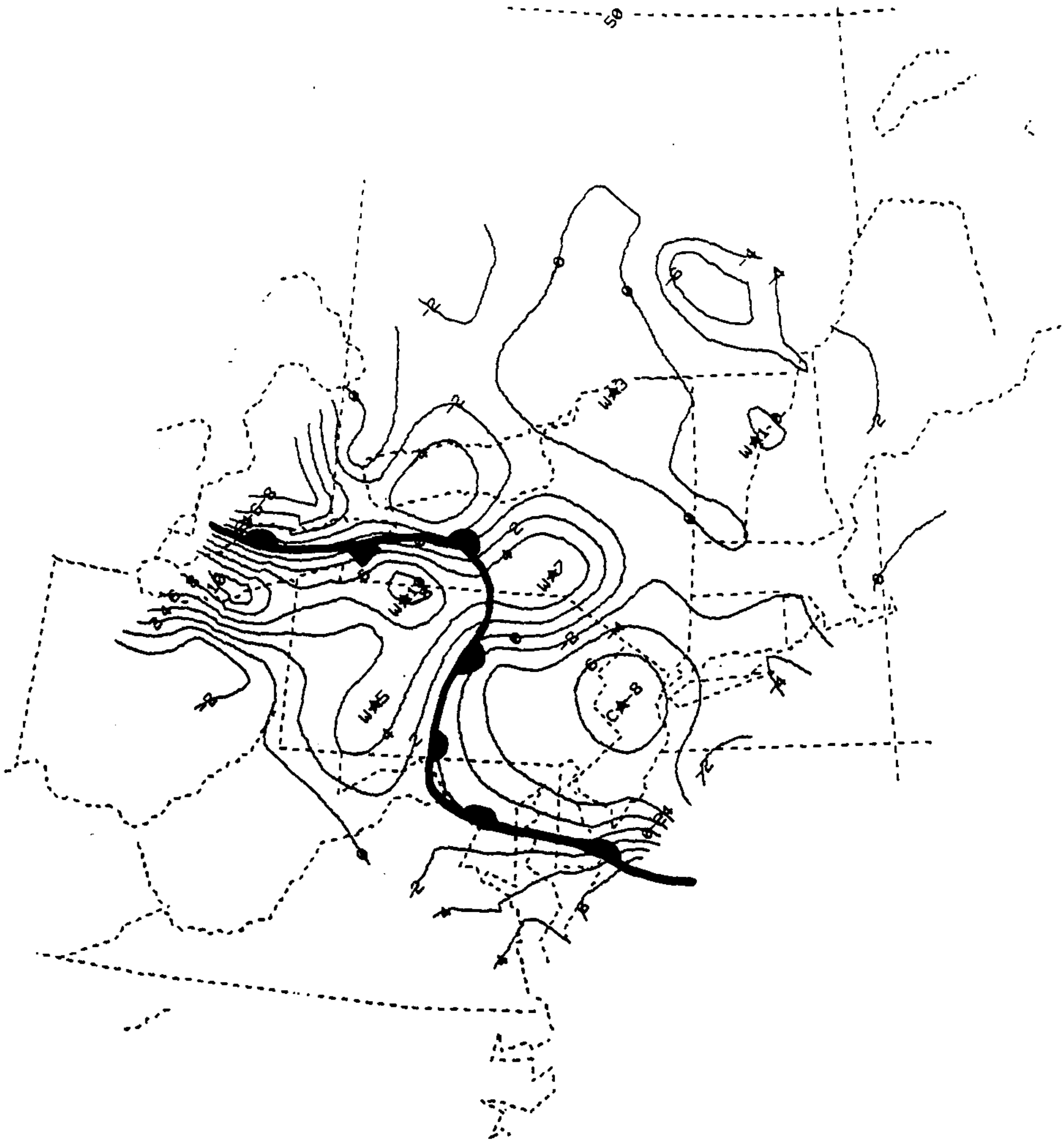

Figure 10. Surface theta advection for 1700 UTC, May 20, 1990.

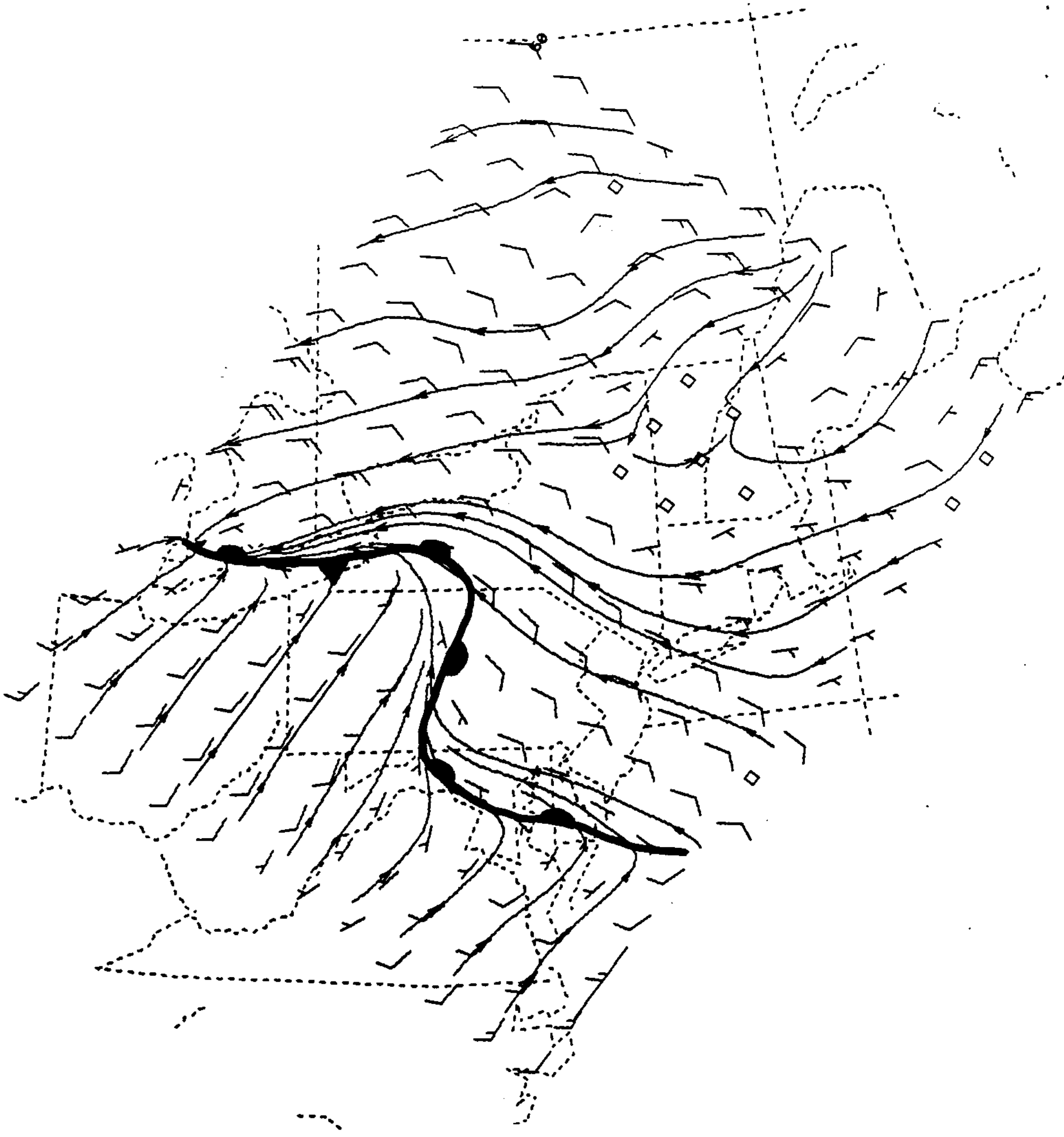

Figure 11. Surface streamlines/wind plot for 1700 UTC, May 20, 1990.

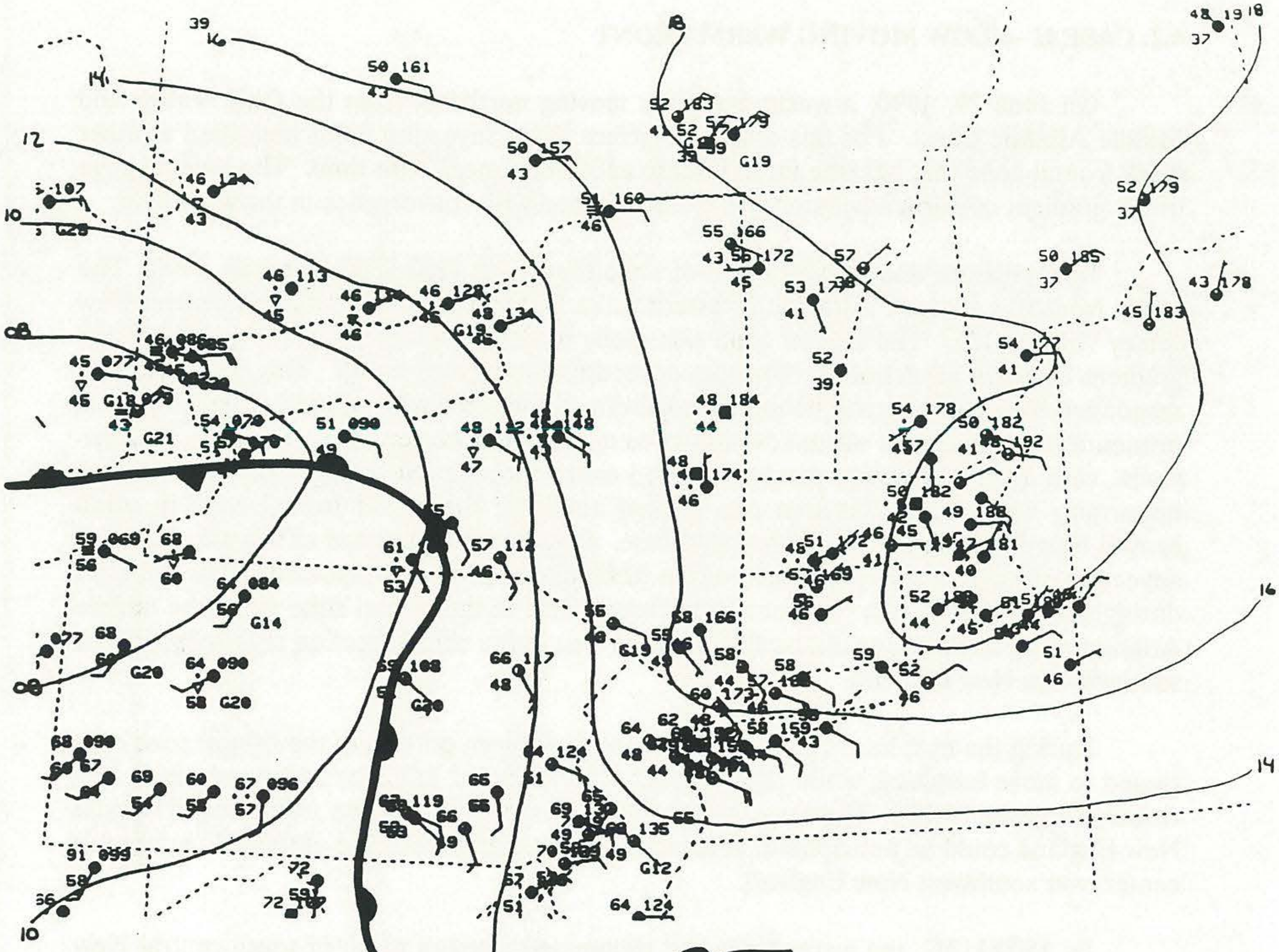

Figure 12. Surface plot and analysis for 1700 UTC, May 20, 1990.

4.2. CASE II - SLOW MOVING WARM FRONT

On June 29, 1990, a warm front was moving northeast from the Ohio Valley and Middle Atlantic Coast. For this case, the surface theta advection fields identified a rather weak frontal zone that became more intense and pronounced with time. The leading edge of the gradient of warm advection was closely aligned with convergence in the wind field.

Low pressure was located north of Lake Huron, at 1200 UTC, June 29, 1990. The warm front was located from southwestern Lake Ontario, southeastward to central New Jersey (Figure 13). The frontal zone was easily identified along the leading edge of the gradient of warm advection in the theta advection chart (Figure 14). This zone also corresponded to a convergence boundary apparent in the streamline output (Figure 15). A pronounced maximum of warm advection was moving into western New York and Pennsylvania, with a cold advection maxima located over southwest New England. A small, but important, warm advection area was located ahead of the actual frontal zone in south central New York, similar to the previous case. Based on the presence of this area of warm advection, some eastward movement of the front might have been expected across this area during the next few hours. Any northward movement of the frontal zone along the middle Atlantic coast, however, would be slow to occur due to the cold advection area present over southwestern New England.

During the next hour (1300 UTC), the northwestern portion of the frontal zone continued to move eastward, while the southeastern portion of the zone remained nearly stationary (Figures 16-18). However, slow northward movement of the front toward coastal New England could be anticipated, in response to the gradual erosion of the cold advection center over southwest New England.

By 1500 UTC, the warm front had progressed through much of south central New York and north central Pennsylvania, as indicated by the STA and SSW analyses (Figures 19 and 20). Note from Figure 20, the winds over southeastern New York and southwestern New England. Earlier (Figures 15 and 18), north winds contributed to cold advection. At 1500 UTC, the winds were calm or light easterly, resulting in neutral advection (or very slight cold advection). The cold advection pattern, which continued to weaken, signaled the possibility that the front would move northeast across northern New Jersey and southeast New York during the next few hours.

At 1700 UTC, the frontal zone extended from Lake Ontario to western Long Island, as depicted in the theta advection and streamline charts, and further supported by the local surface plot (Figures 21-23). The warm advection that continued in advance of the frontal zone over eastern New York, made placement of the frontal location based on the theta advection analysis alone somewhat difficult. However, the location of the frontal zone over eastern New York was quite evident from the streamline analysis.

By 1900 UTC, the theta advection chart indicated the warm frontal zone had continued to advance northeastward into eastern New York and extreme southwestern New England (Figure 24). The inverted trough (Figure 25) in the streamline analysis along the southern New England coast, suggested that the front was just offshore. The lack of marine observations in this analysis, might lead one to question this conclusion. A look at the local surface plot at 1900 UTC (Figure 26), however, supported this frontal position based on a dew point of 71°F for Block Island, RI (BID). This represented a 5°F rise over a 2-hour period.

As for the previous case, the greatest forward movement of the front (across eastern New York) was over the area where warm advection occurred ahead of the front several hours earlier. The slower northward movement of the front, into coastal New England was likely the result of the cool easterly wind flow off the Atlantic, a common feature during the spring and early summer. Also, we note that the movement of the frontal zone into northern New York (across Lake Ontario) was inhibited by an area of cold advection that developed and strengthened during the previous 6 hours.

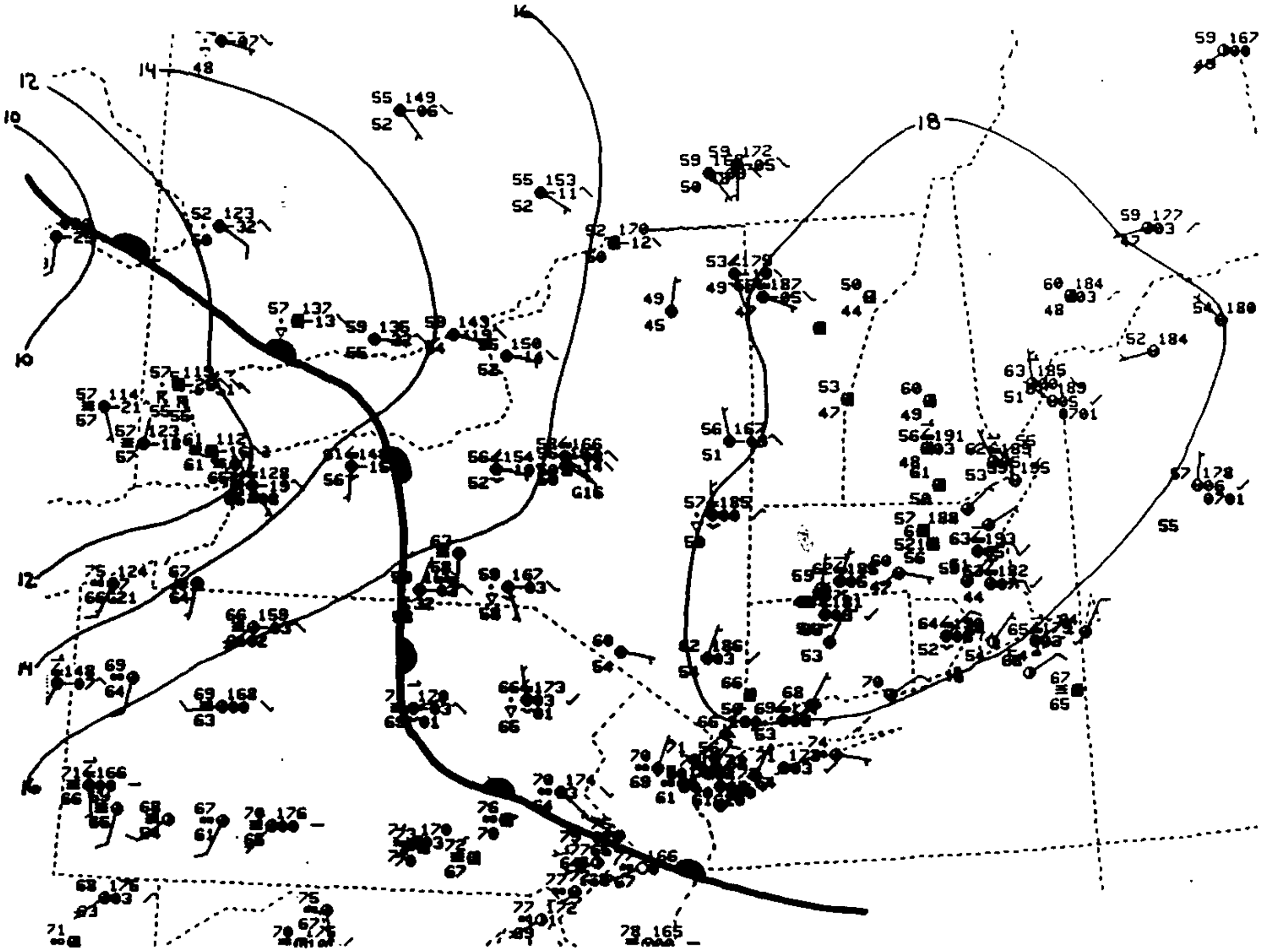

Figure 13. Surface plot and analysis for 1200 UTC, June 29, 1990.

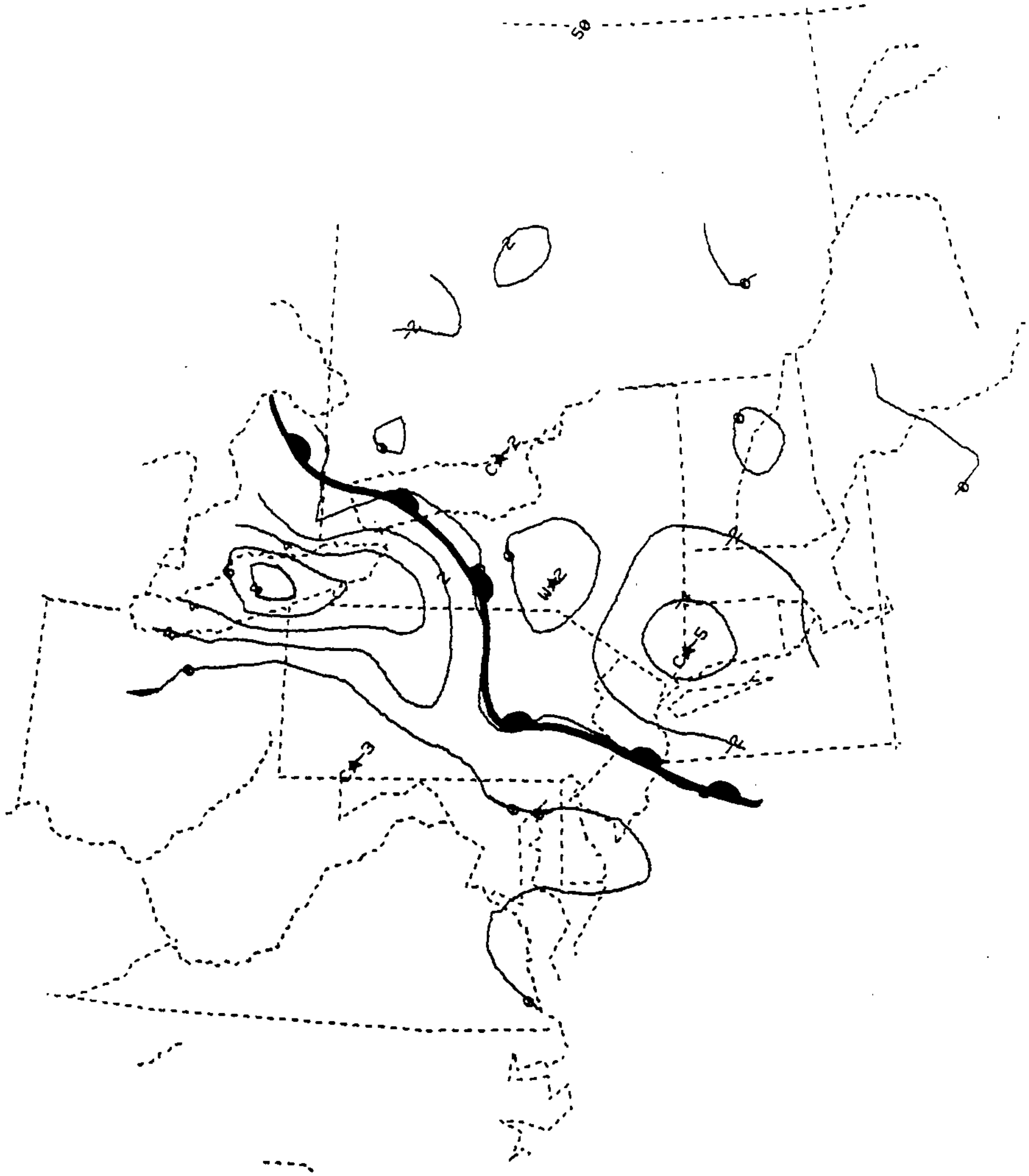

Figure 14. Surface theta advection for 1200 UTC, June 29, 1990.

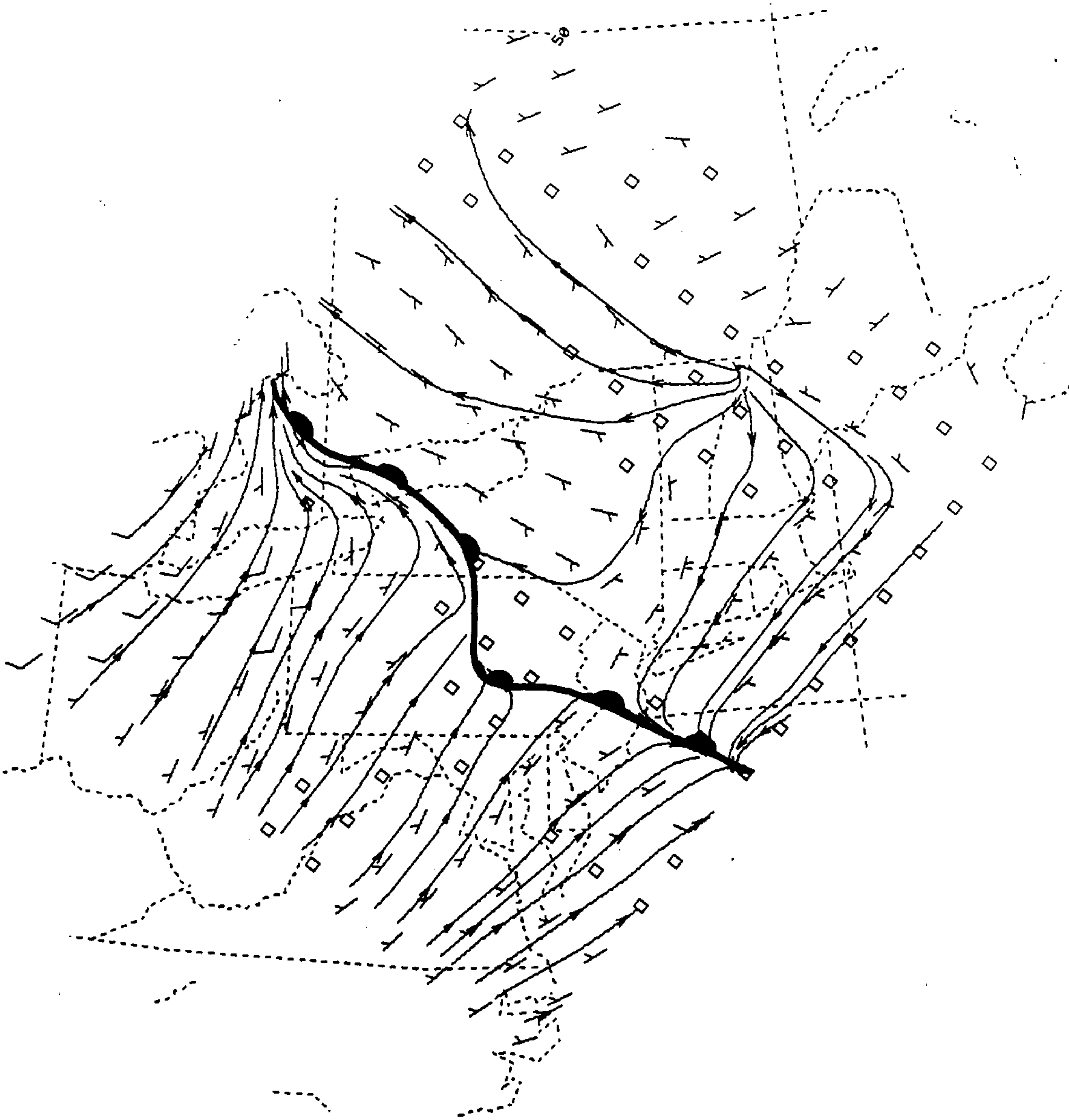

Figure 15. Surface streamlines/wind plot for 1200 UTC, June 29, 1990.

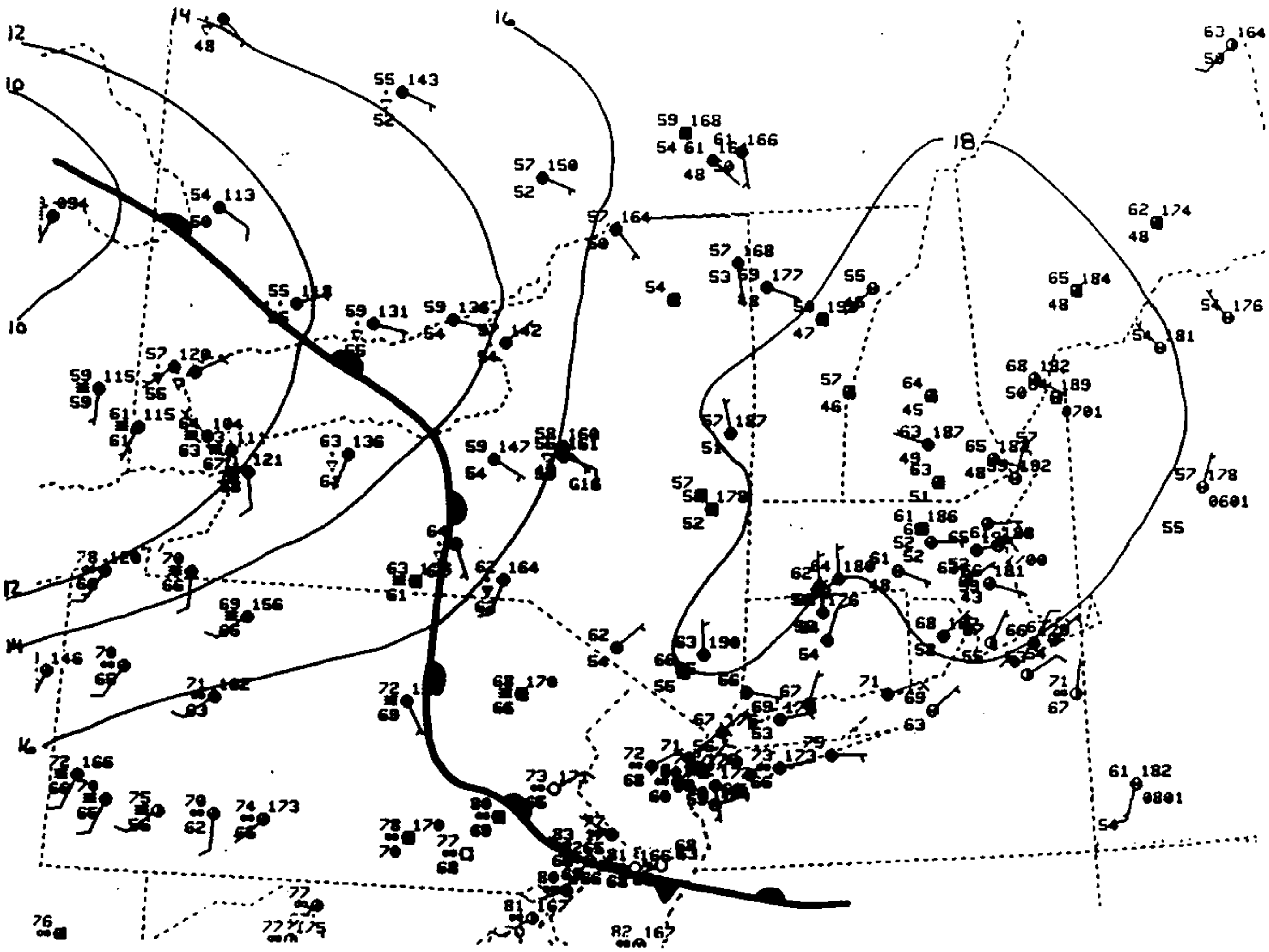

Figure 16. Surface plot and analysis for 1300 UTC, June 29, 1990.

Figure 17. Surface theta advection for 1300 UTC, June 29, 1990.

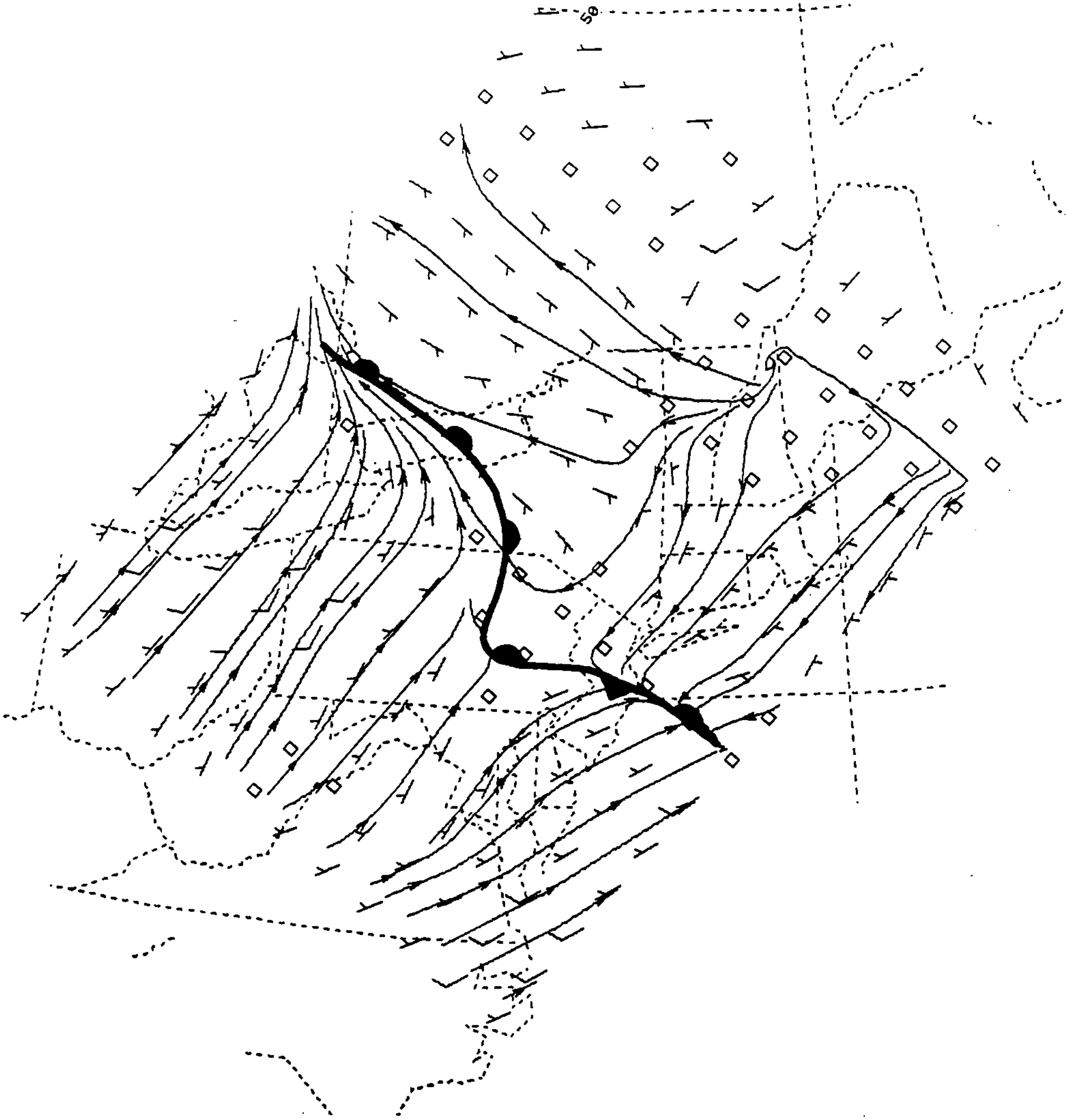

Figure 18. Surface streamlines/wind plot for 1300 UTC, June 29, 1990.

Figure 19. Surface theta advection for 1500 UTC, June 29, 1990.

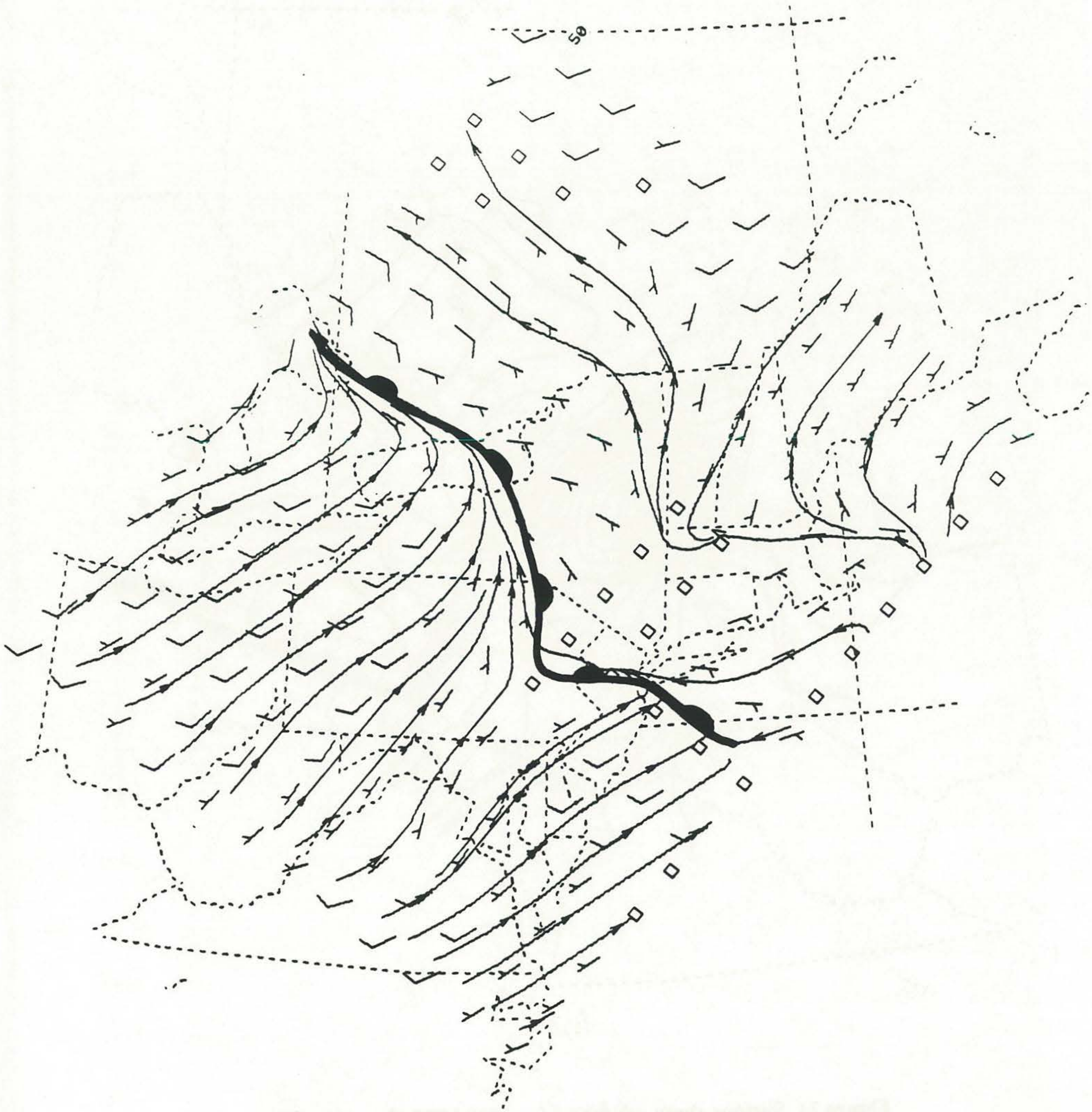

Figure 20. Surface streamlines/wind plot for 1500 UTC, June 29, 1990.

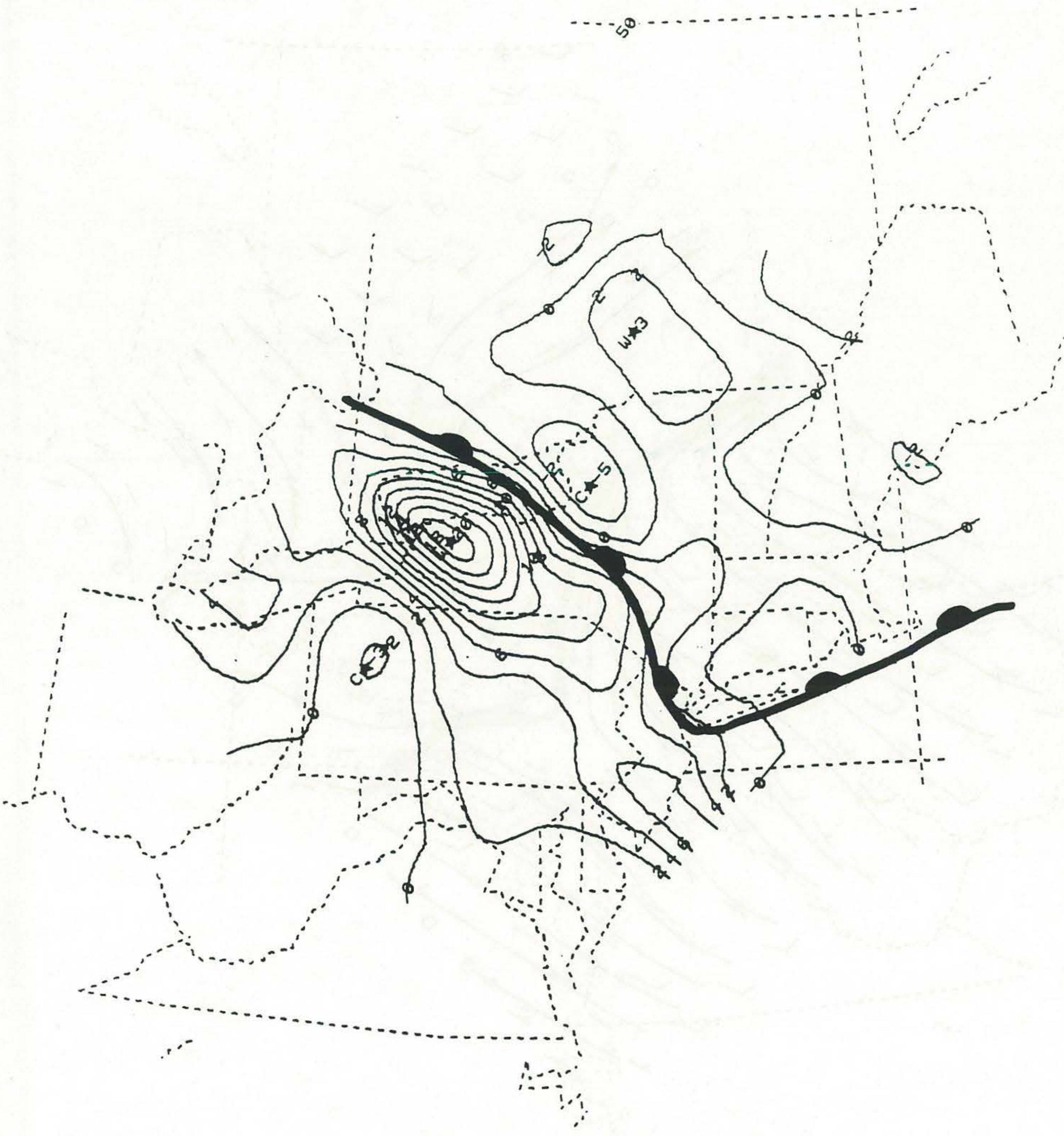

Figure 21. Surface theta advection for 1700 UTC, June 29, 1990.

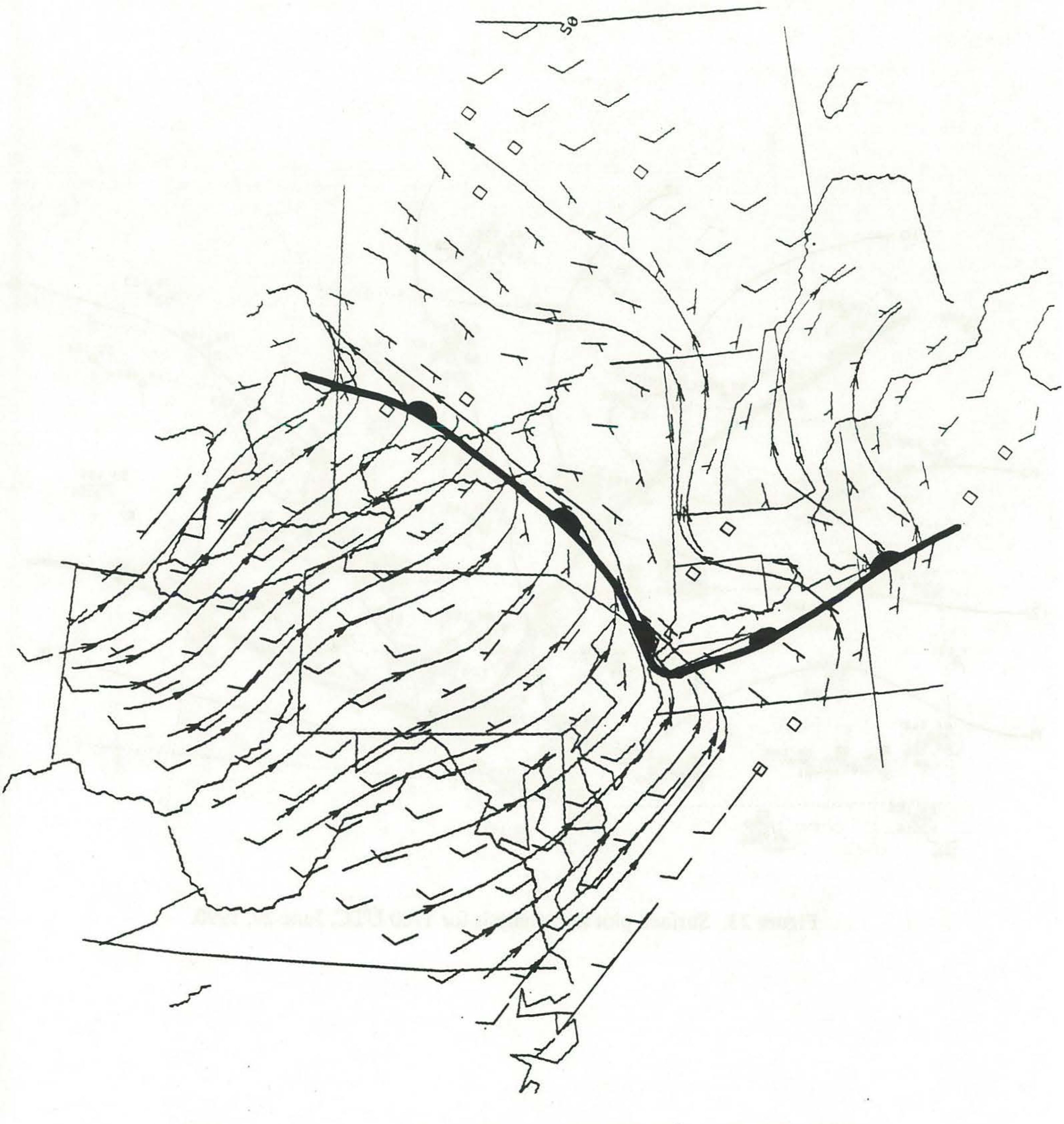

Figure 22. Surface streamlines/wind plot for 1700 UTC, June 29, 1990.

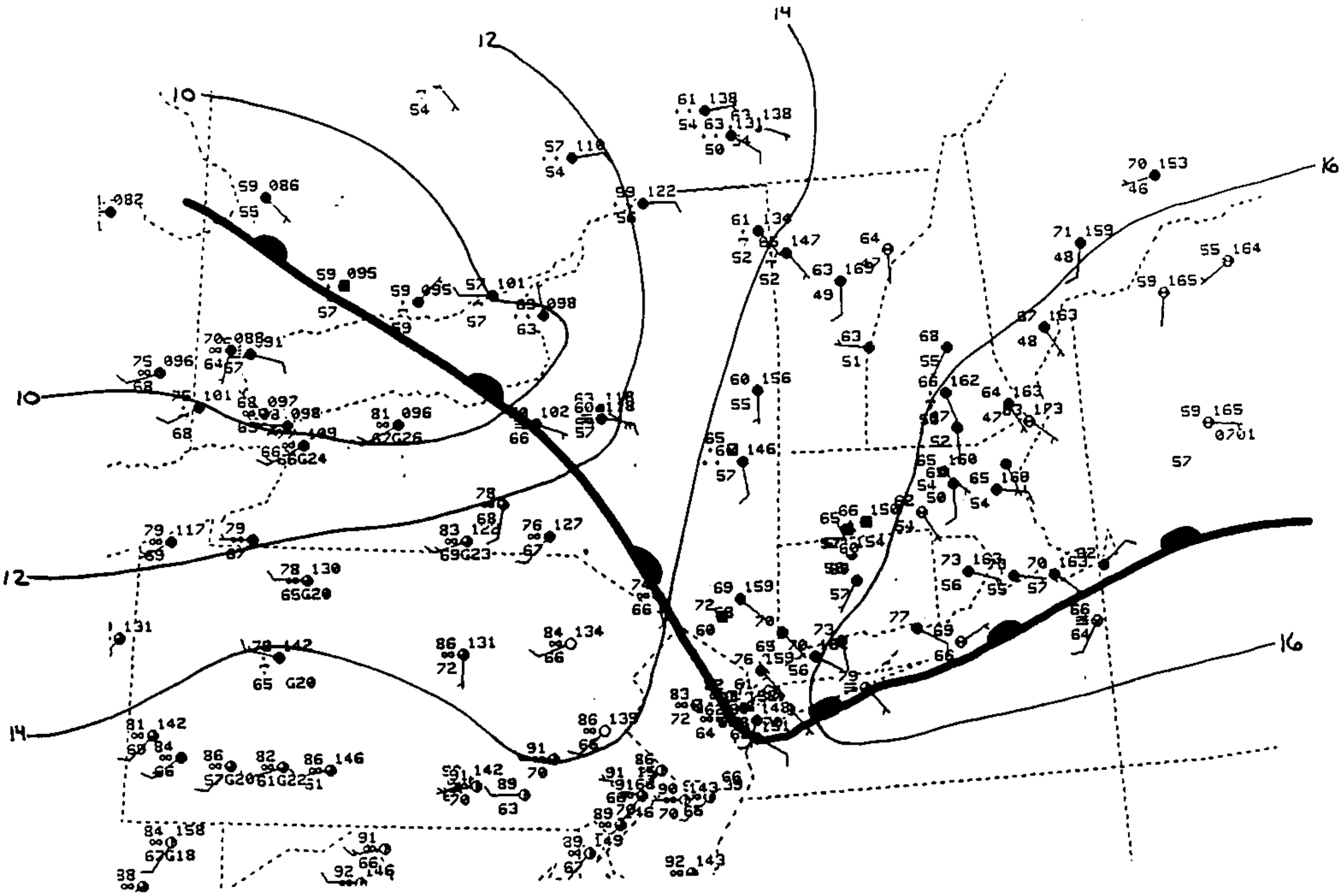

Figure 23. Surface plot and analysis for 1700 UTC, June 29, 1990.

Figure 24. Surface theta advection for 1900 UTC, June 29, 1990.

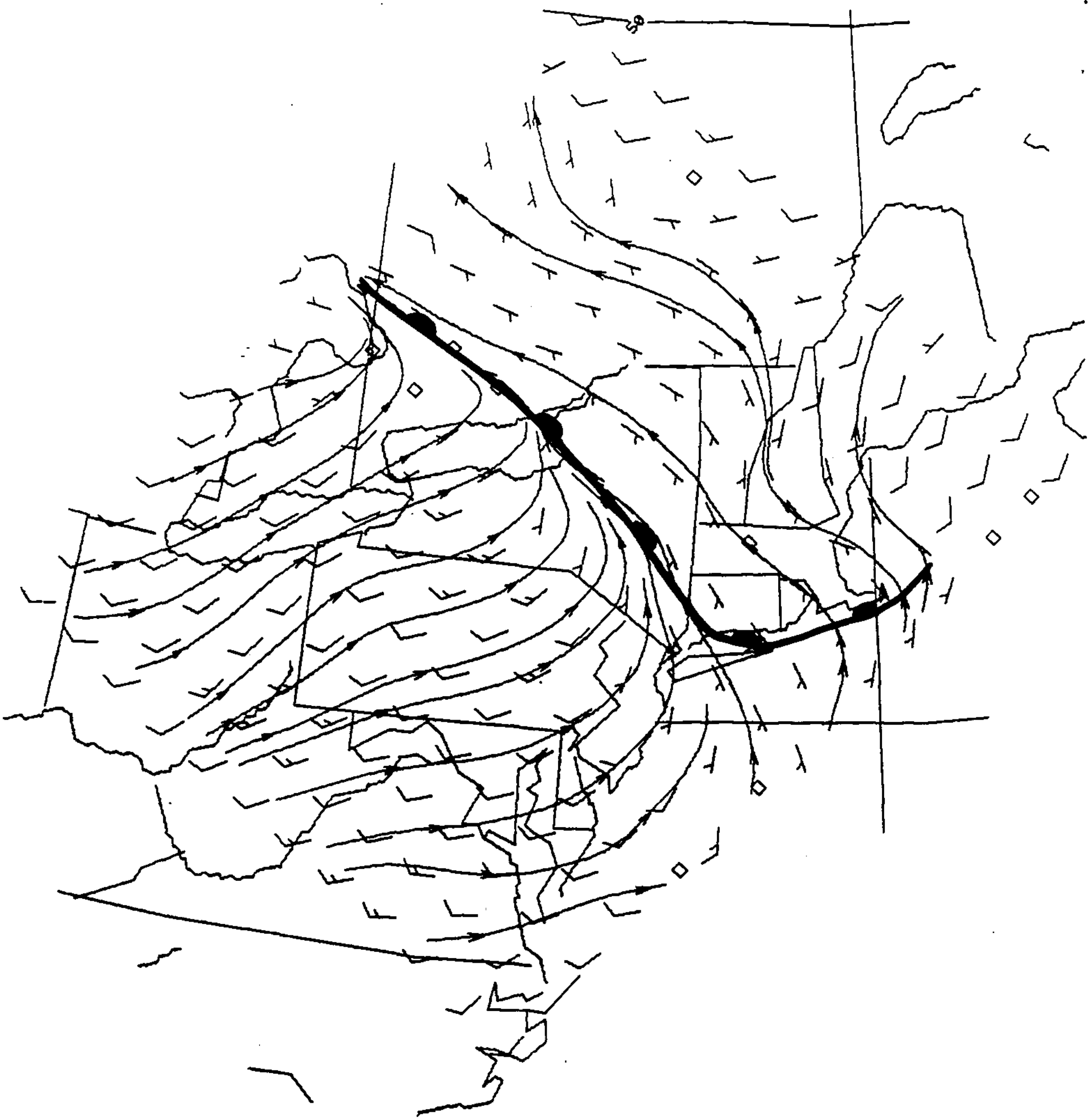

Figure 25. Surface streamlines/wind plot for 1900 UTC, June 29, 1990.

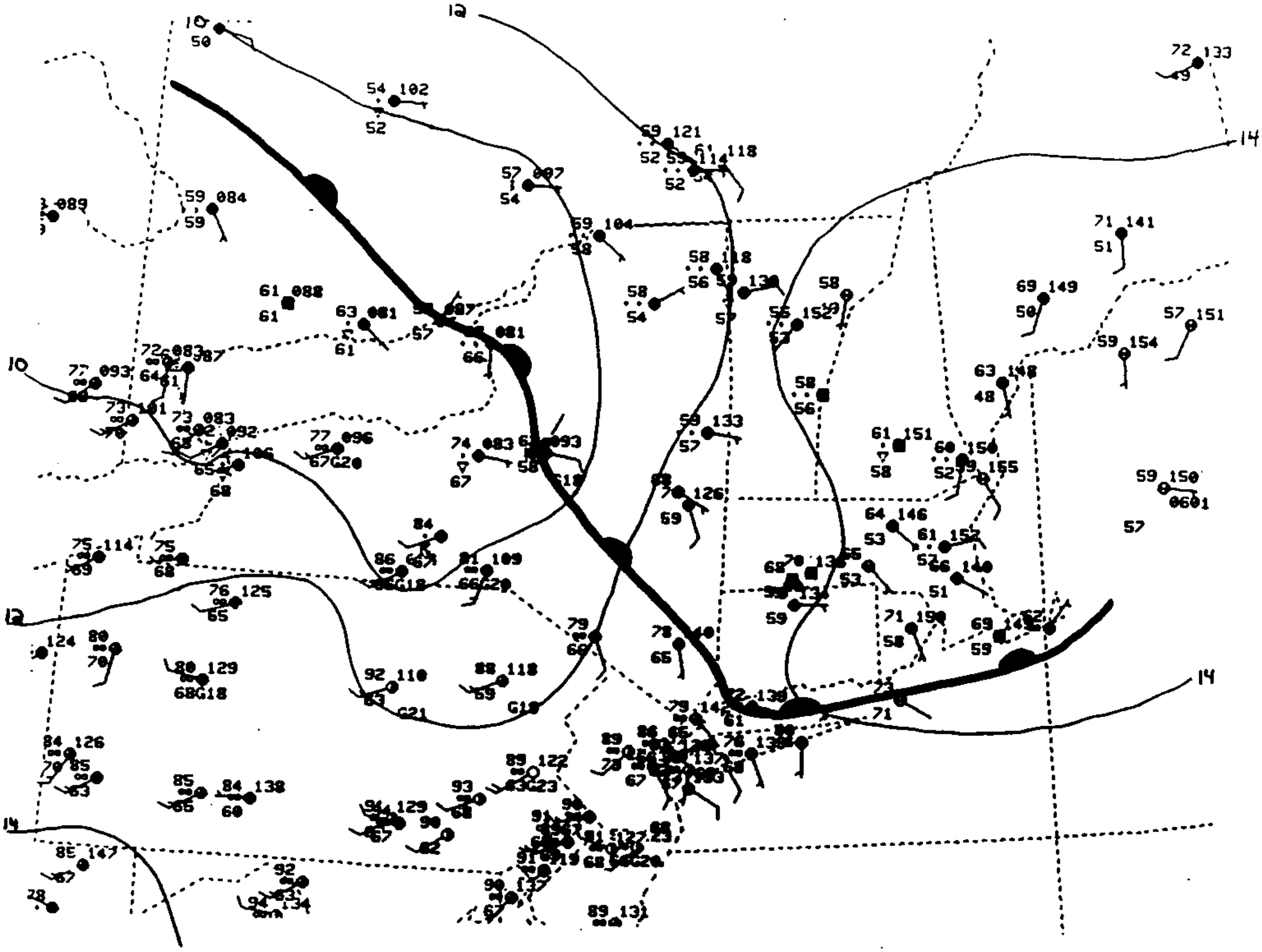

Figure 26. Surface plot and analysis for 1900 UTC, June 29, 1990.

4.3. CASE III - FAST MOVING WARM FRONT

For this case, the theta advection output successfully identified the movement of the western portion of a warm frontal zone across central Pennsylvania and New York. The analysis had more difficulty identifying a boundary across coastal New England until the front moved inland. The ADAP output was able to identify two persistent regions of warm advection that developed in advance of the front. One formed across southern New England, while a second area was over northern New York, which lead to a rapid surge of the frontal zone into northwestern New England.

In particular, by 0800 UTC, November 11, 1990, a warm front was located from eastern Lake Huron, southward through the West Virginia panhandle into northern Virginia. The front then curved sharply northeastward into central New Jersey (Figures 27 and 28). The eastern portion of the boundary, located south of the New England coast, was not clearly identifiable in the theta advection field or streamline/wind output. The surface plot, however, suggested that the zone was located along the south shore of Long Island, as indicated by south winds and higher dew points (Figure 29). Even this analysis was questionable due to the inability of ADAP to utilize marine data, and because several observation sites are closed at night. Cold air was entrenched across much of New England, eastern New York, and eastern Pennsylvania. Strong warm advection was evident from extreme western New York southward through northern West Virginia.

By 1000 UTC, the cold advection over eastern Pennsylvania and central New York persisted, resulting in little eastward advance of the frontal zone (Figures 30 and 31). Note, the warm advection that developed ahead of the front across northern New York and southern Ontario.

By 1200 UTC, the surface analysis (Figure 32) showed that the front had moved into coastal Connecticut, extending eastward to the southern tip of Cape Cod, as indicated by significant dew point rises and the southerly wind. Note how many more stations reported at 1200 UTC compared to 0800 UTC (Figure 29). Of course, some of the observations near the coast are ship and/or U. S. Coast Guard observations that only report during synoptic times. The theta advection and streamline analyses (Figures 33 and 34) continued to show a slow eastward movement of the boundary across central New York and Pennsylvania.

To the north, however, where warm advection had developed ahead of the front, the front moved more rapidly into the region east of Lake Ontario. Warm advection continued over northern New York ahead of the boundary. In addition, some warm advection was evident across southeastern New England. Meanwhile, cold advection held firm from central New England southwest to northeast Pennsylvania.

By 1400 UTC, the theta advection and streamline charts (Figures 35 and 36) indicated a slight retreat to the northeast of the cold advection over Pennsylvania as the front made slow eastward progression across the state. Note, the light east and northeast winds evident earlier over eastern Pennsylvania (Figures 31 and 34), were now south and southwest. Over northern New York, the front continued to more rapidly to the east.

The low center was now evident in the streamline analysis (Figure 36) over southern Ontario, northeast of Lake Huron. The STA chart helped to identify the cold front moving into the eastern Great Lakes. Across southern New England, warm advection continued, with the strongest warm advection located over southeastern Massachusetts. The frontal position in this area continued to be best defined by the surface plot, which suggested that the front was beginning to back in toward the coast from southeast to northwest (Figure 37). The STA chart show increasing warm advection over southern New England, indicating that the front should begin to make more rapid progress inland.

During the next 2 hours, the warm front appeared to advance rapidly into southern New England. By 1600 UTC, the frontal zone was located much further north into southern Vermont and New Hampshire (Figures 38-40). Rapid erosion of the cold center across New York, in combination with the warm advection in advance of the frontal zone over southern New England, resulted in this "jump," or reformation of the front across central New England. This warm frontal "reformation" occurs frequently in the Northeast when cold air at the surface is eroded from above by overrunning warm air. Eventually, the warm front aloft works its way down to the surface.

While cold advection was no longer apparent, however, a minimum of warm advection was still centered over central New Hampshire (Figure 38), indicating some weak cold air damming was still occurring over northern New England. Also, note, the eastward progress of the front slowed considerably across northern New York during the 2-hour period. This was probably the result of low level cold air being trapped in the Champlain and Connecticut River Valleys. Finally, the low center continued to move northeast during the period, with the associated cold front evident moving into western New York and northwest Pennsylvania.

The theta advection output was a key indicator that rapid movement into southern New England would occur. The STA charts revealed an increase in magnitude and aerial coverage of warm advection (and weakening/retreat of the cold advection associated with damming) ahead of the boundary. The only problem was that the output did not clearly identify the frontal boundary as it approached the coast. In addition, a broad southerly flow in the streamline pattern eliminated the use of a wind shift/convergence boundary as a frontal indicator. This was the only case studied where the combination of both fields failed to provide a more exact position to the frontal zone. The local surface plots, however, were necessary to better define the precise frontal location over the coastal waters.

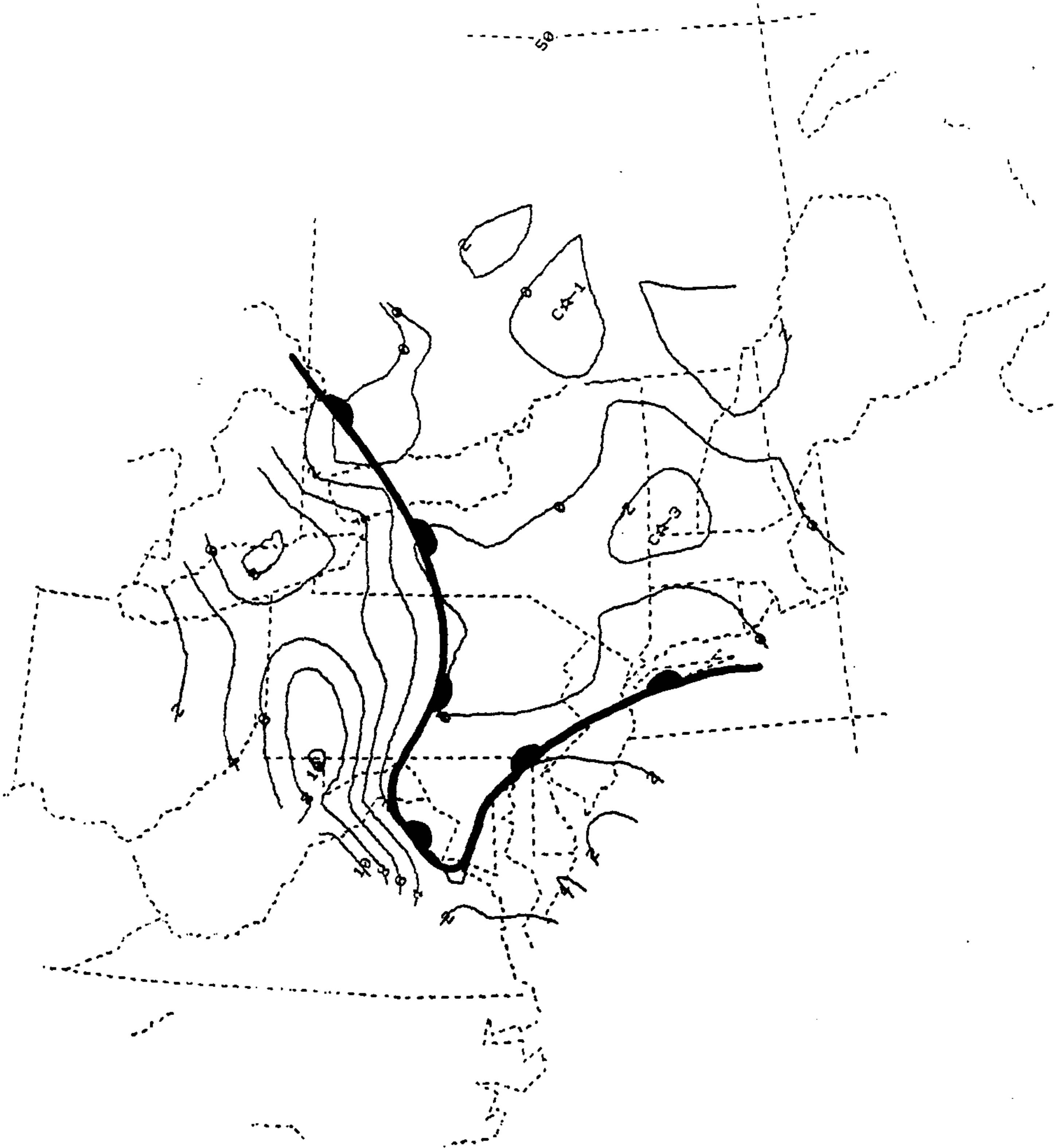

Figure 27. Surface theta advection for 0800 UTC, November 11, 1990.

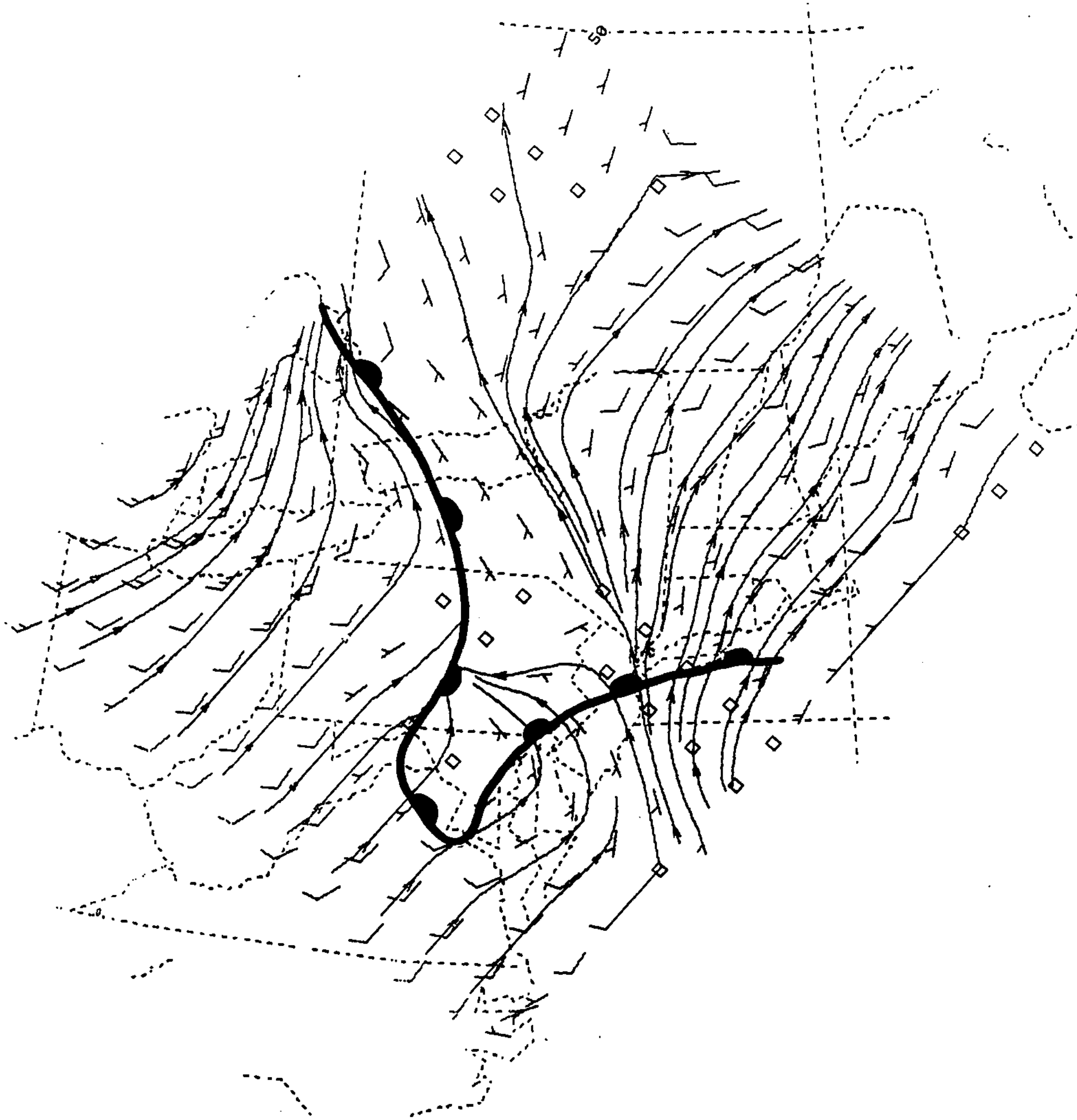

Figure 28. Surface streamlines/wind plot for 0800 UTC, November 11, 1990

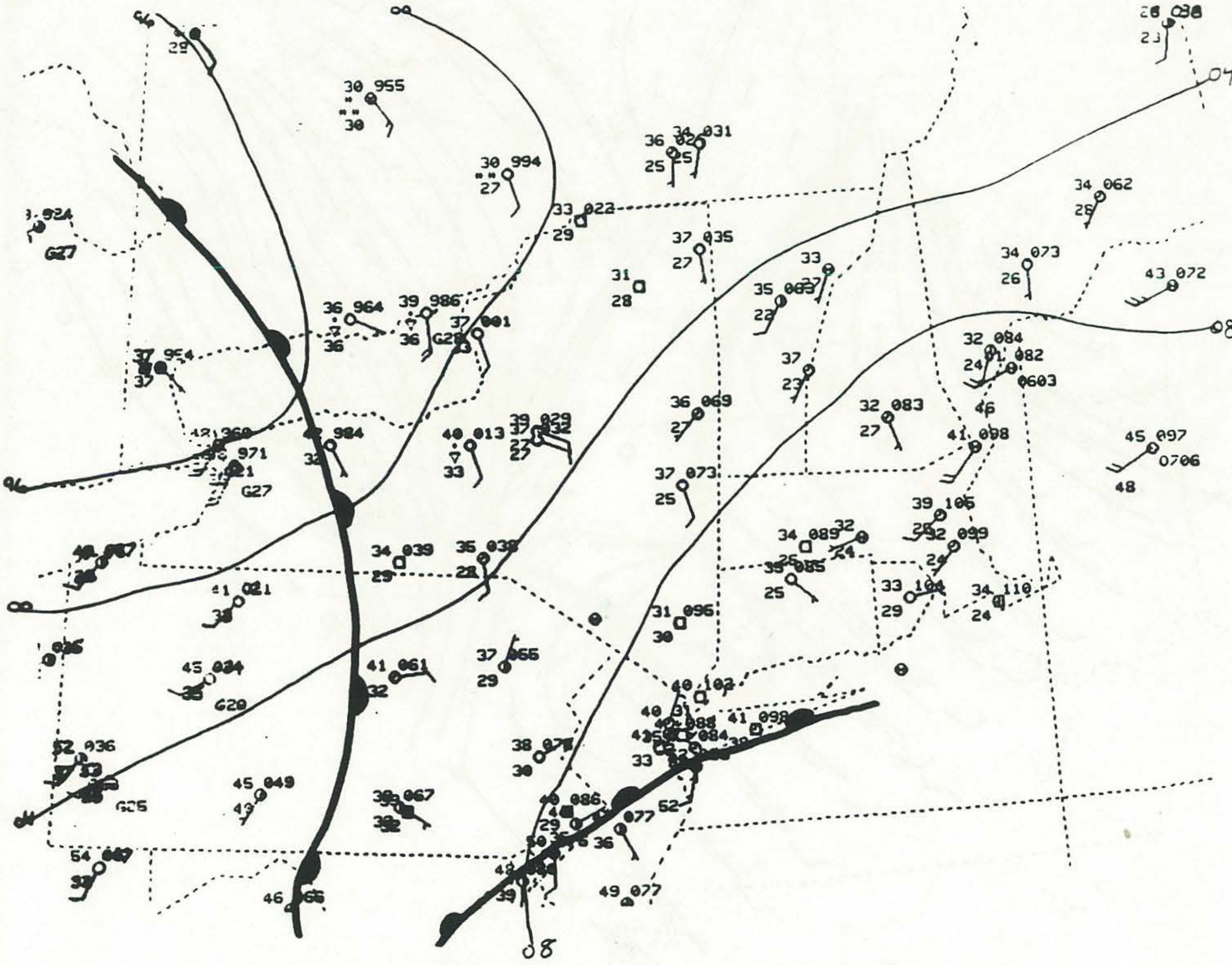

Figure 29. Surface plot and analysis for 0800 UTC, November 11, 1990.

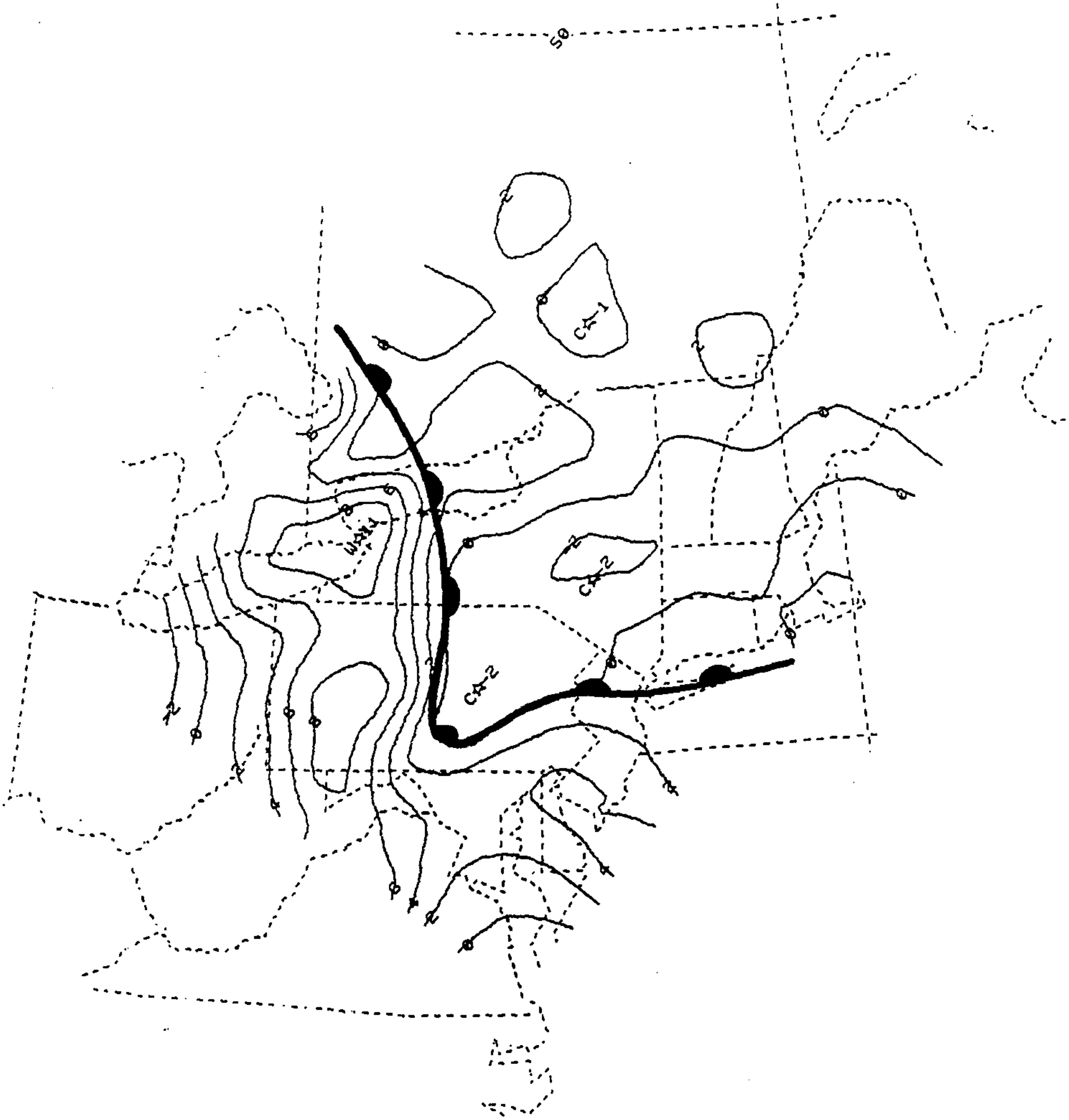

Figure 30. Surface theta advection for 1000 UTC, November 11, 1990.

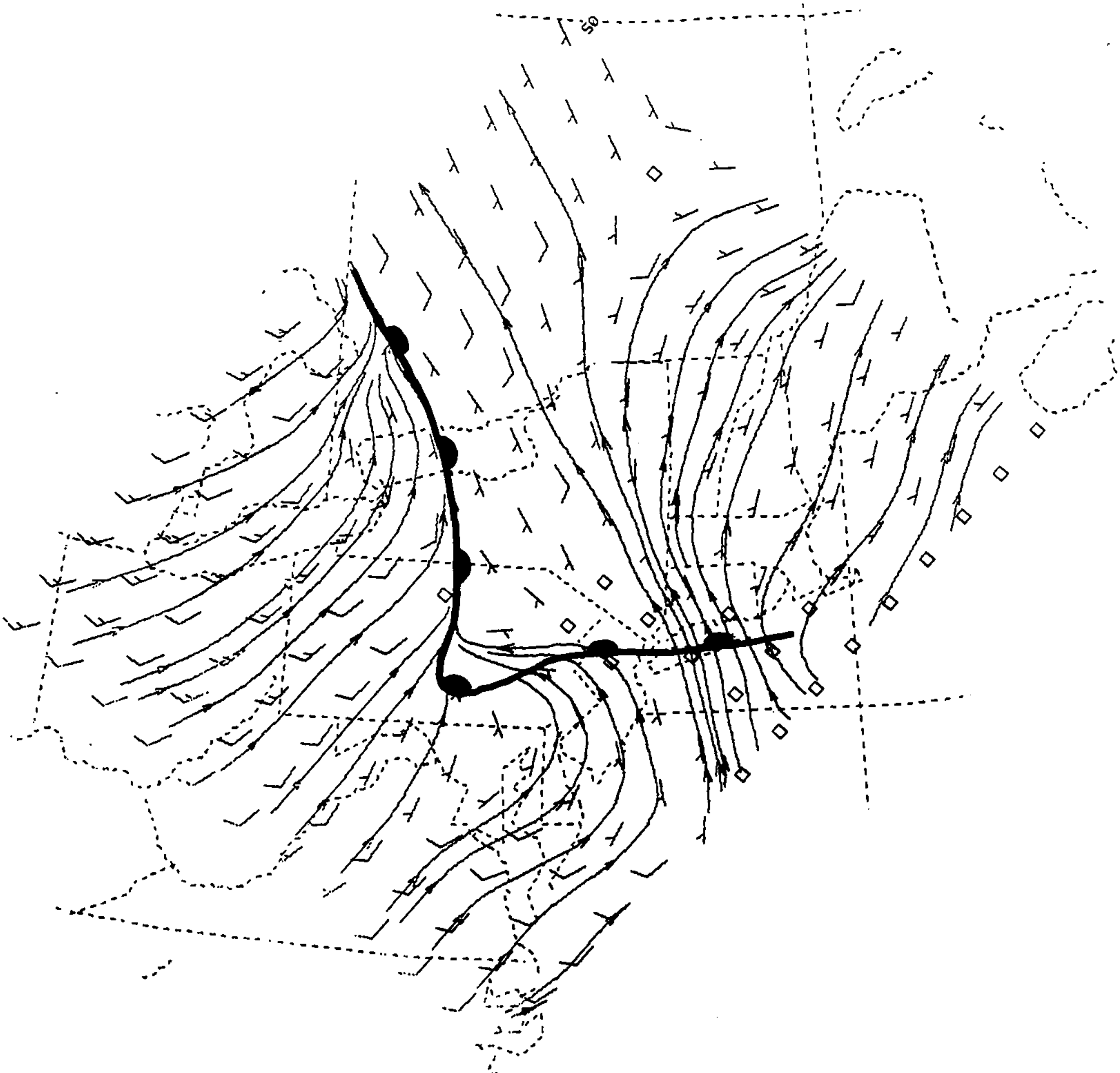

Figure 31. Surface streamlines/wind plot for 1000 UTC, November 11, 1990.

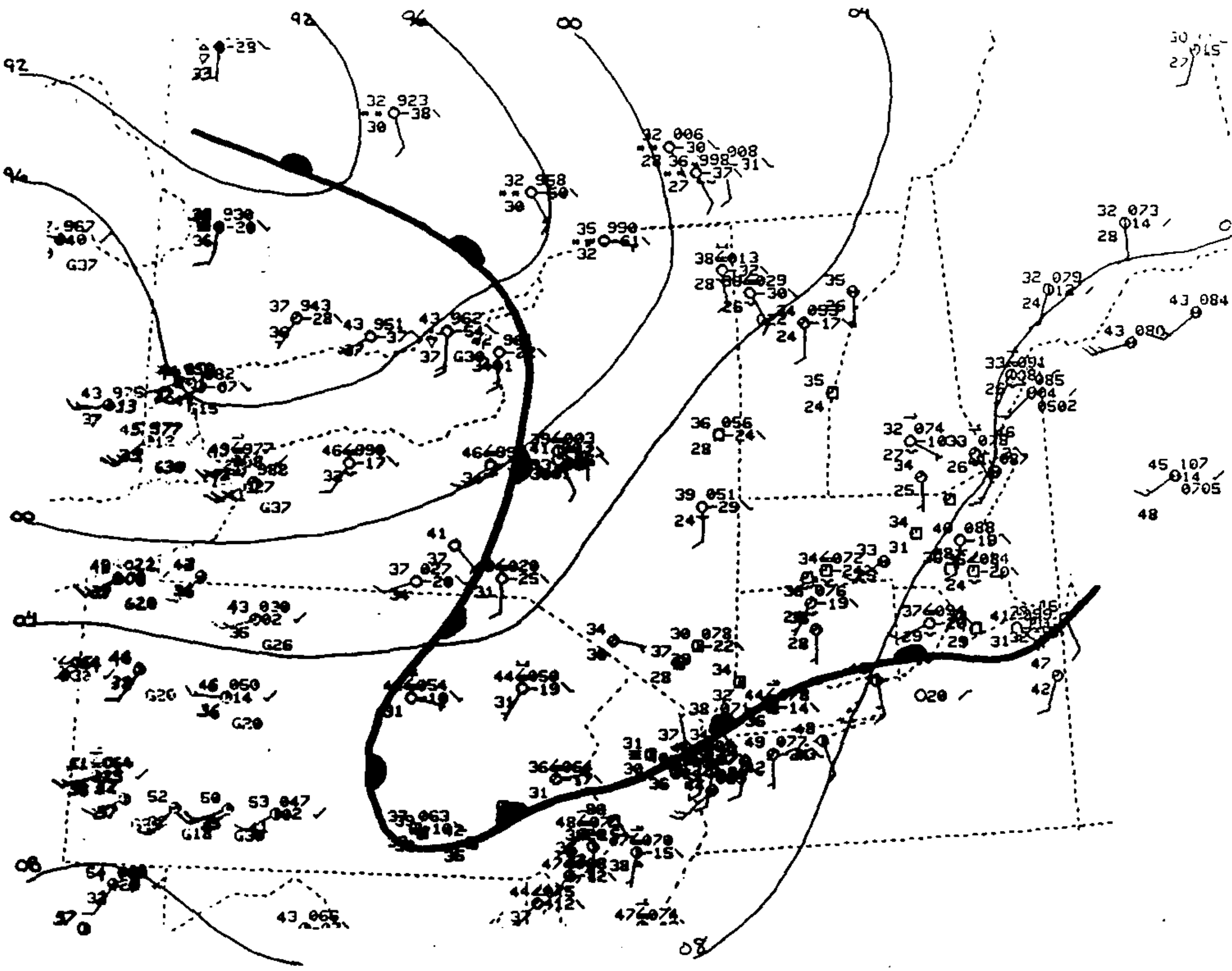

Figure 32. Surface plot and analysis for 1200 UTC, November 11, 1990.

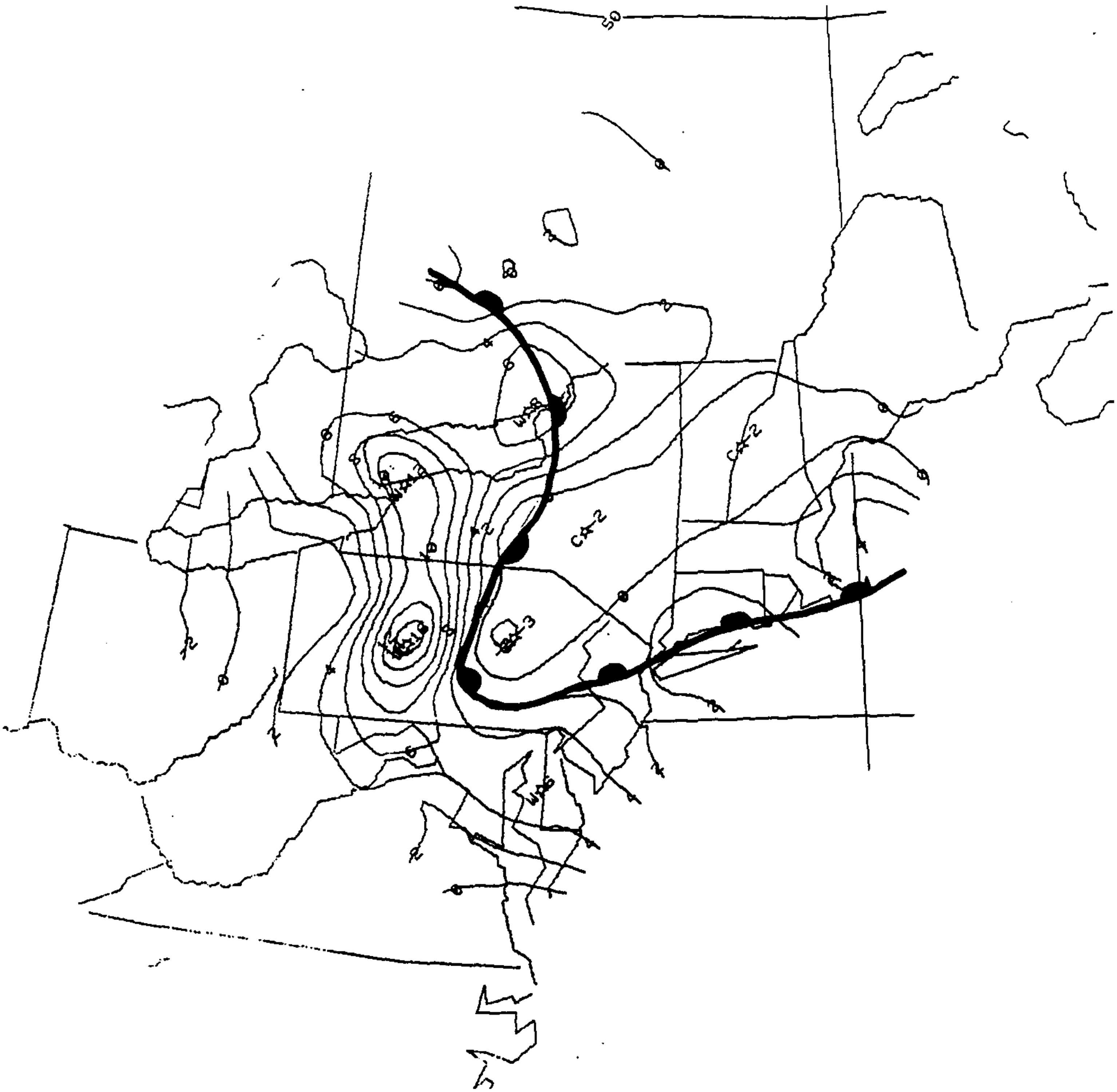

Figure 33. Surface theta advection for 1200 UTC, November 11, 1990.

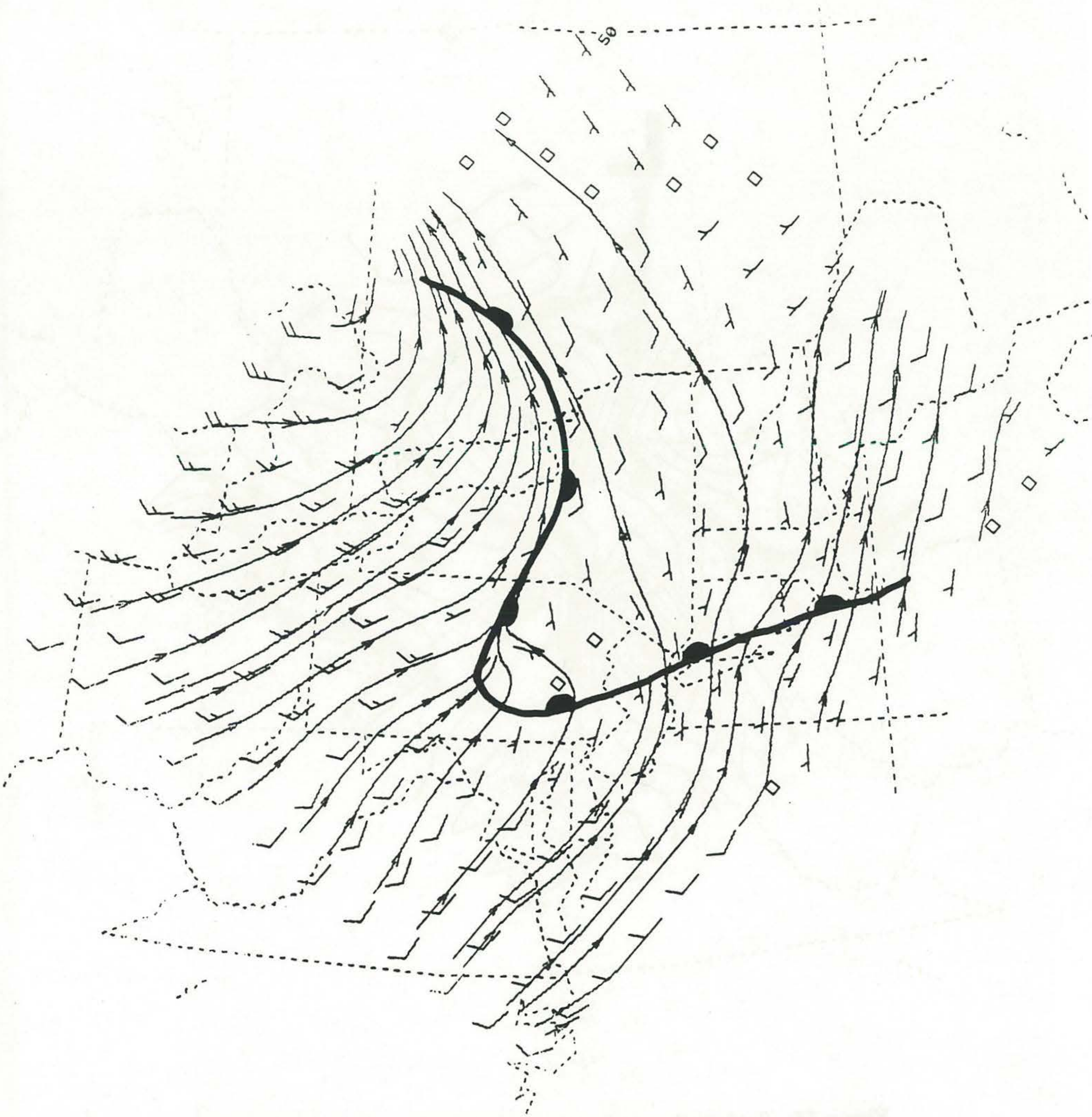

Figure 34. Surface streamlines/wind plot for 1200 UTC, November 11, 1990.

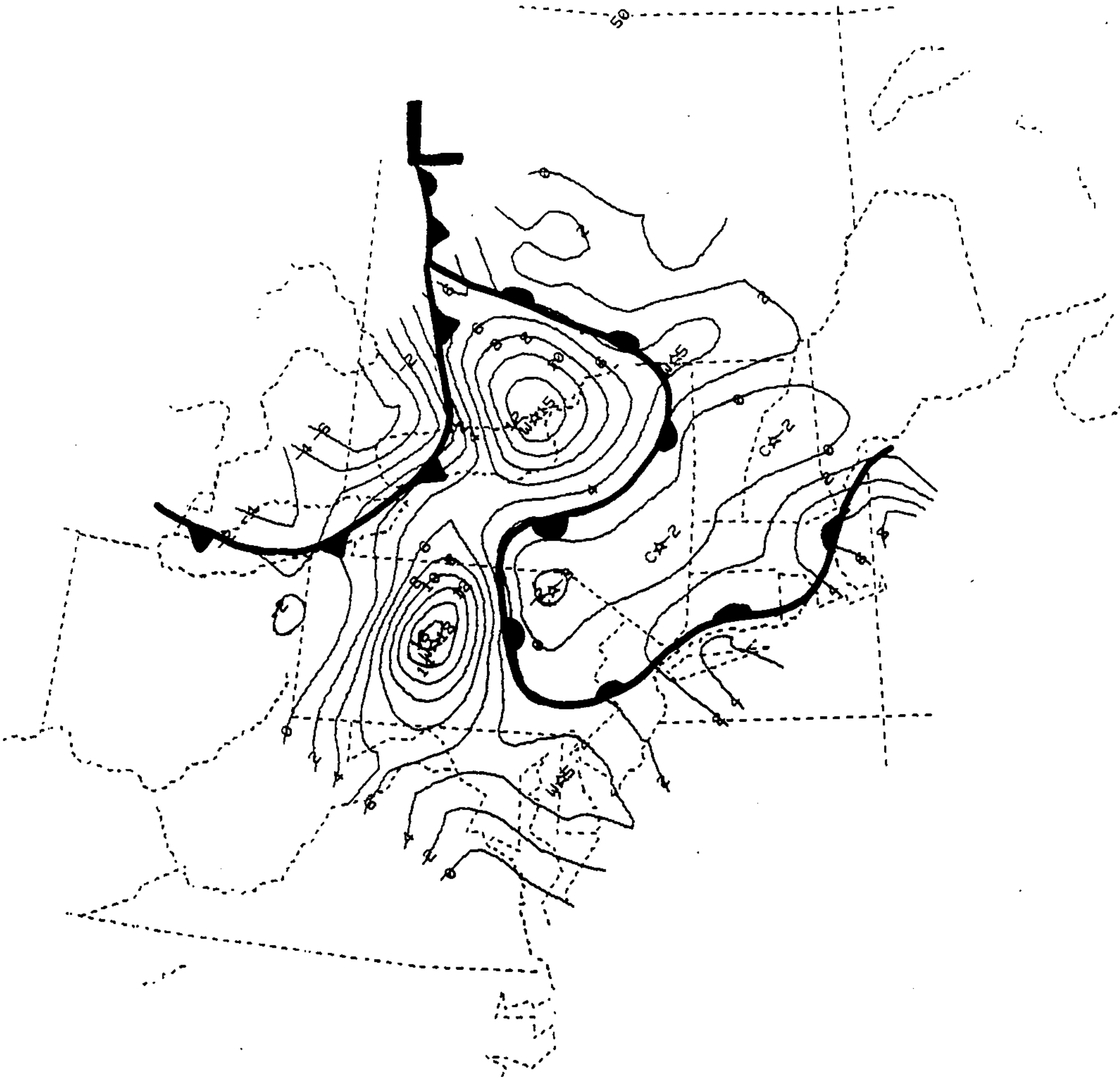

Figure 35. Surface theta advection for 1400 UTC, November 11, 1990.

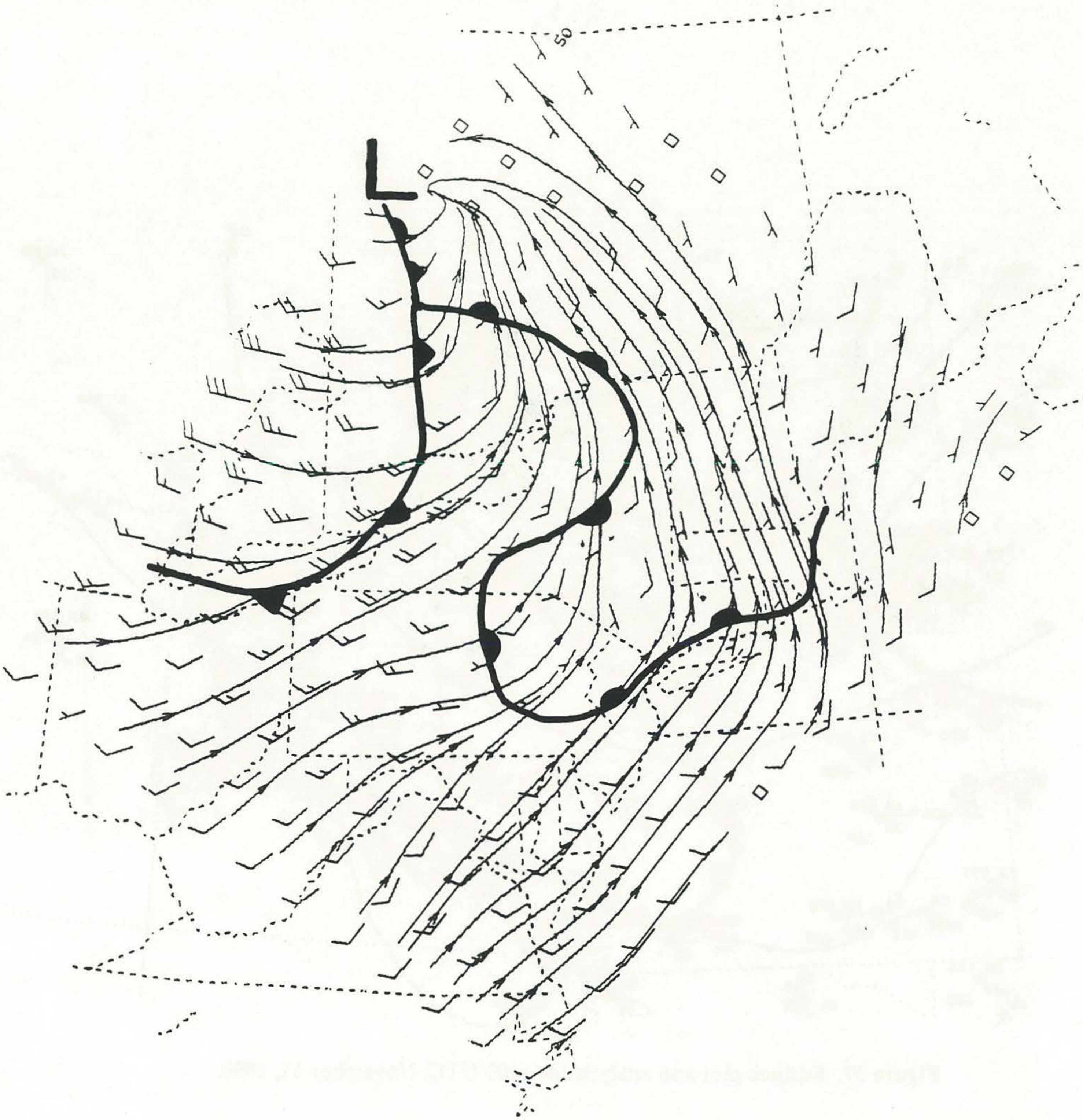

Figure 36. Surface streamlines/wind plot for 1400 UTC, November 11, 1990.

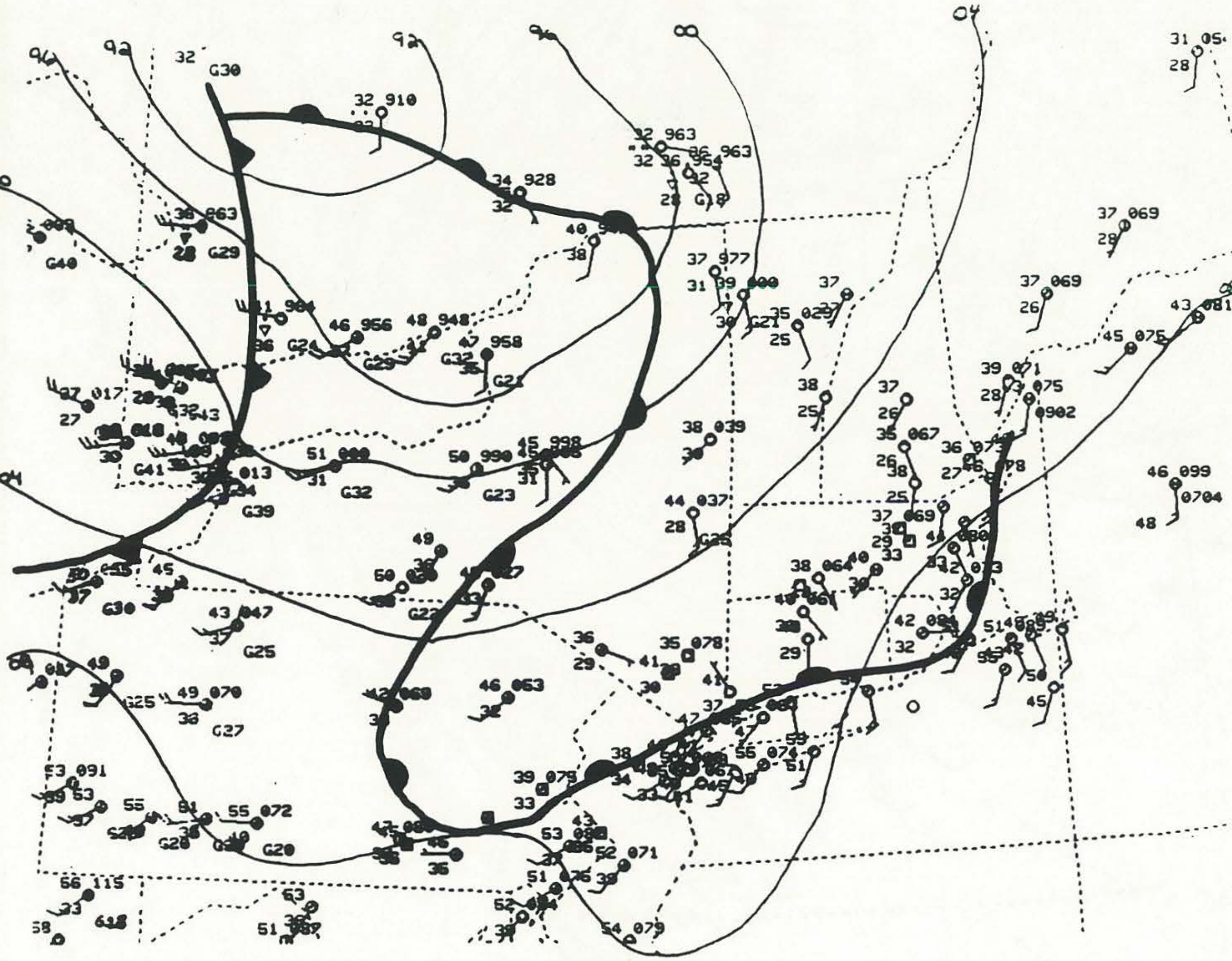

Figure 37. Surface plot and analysis for 1400 UTC, November 11, 1990.

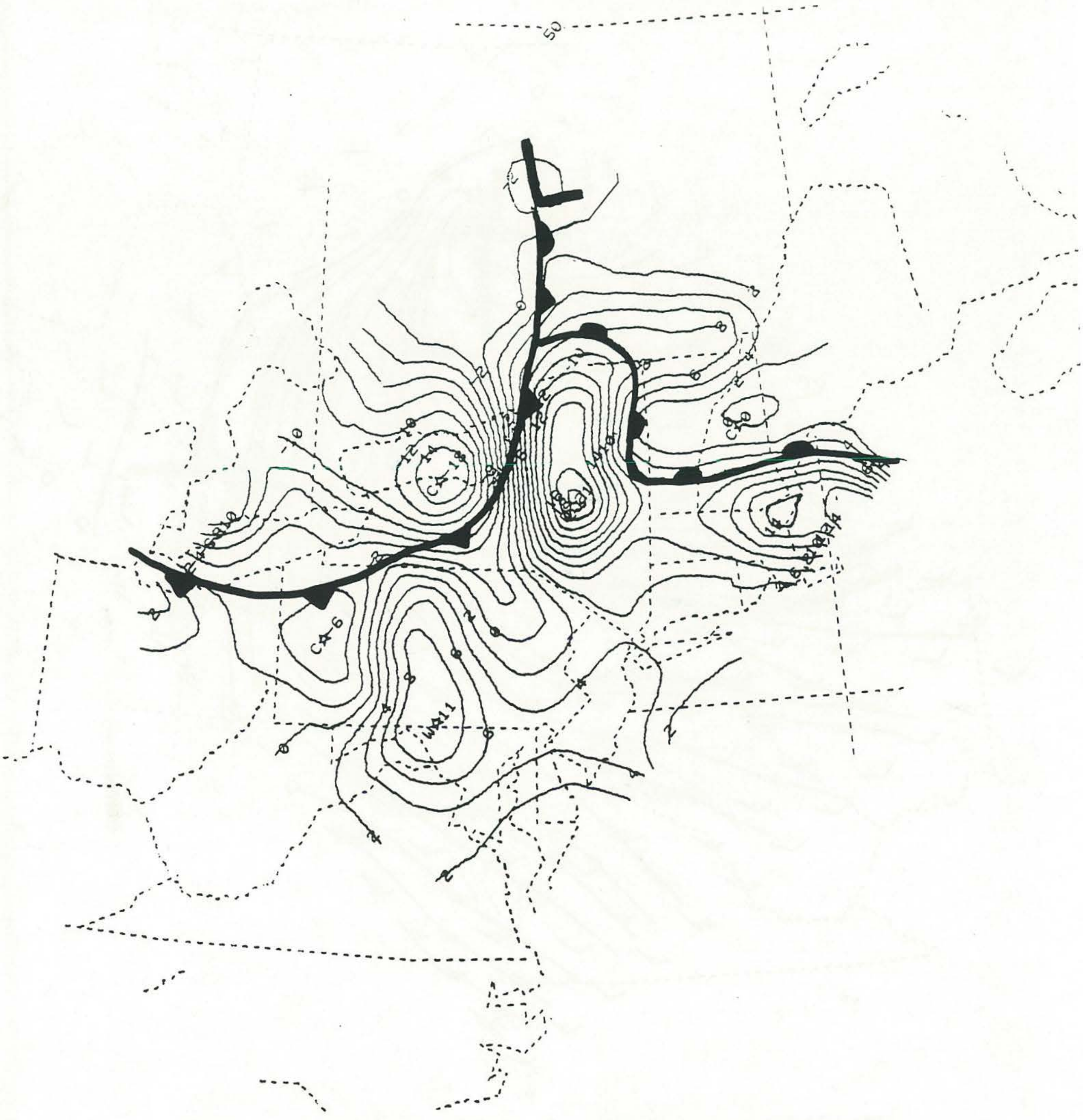

Figure 38. Surface theta advection for 1600 UTC, November 11, 1990.

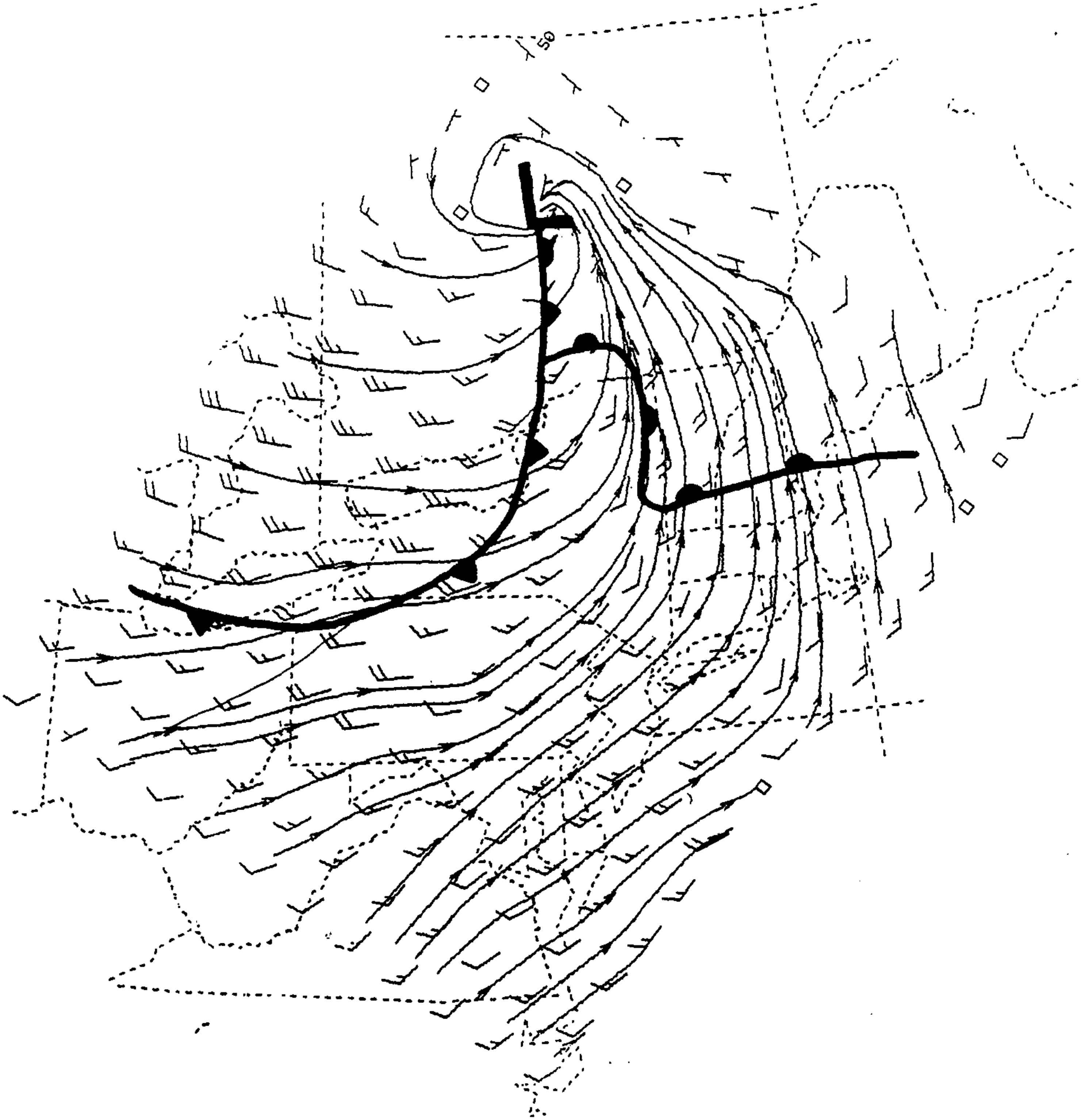

Figure 39. Surface streamlines/wind plot for 1600 UTC, November 11, 1990.

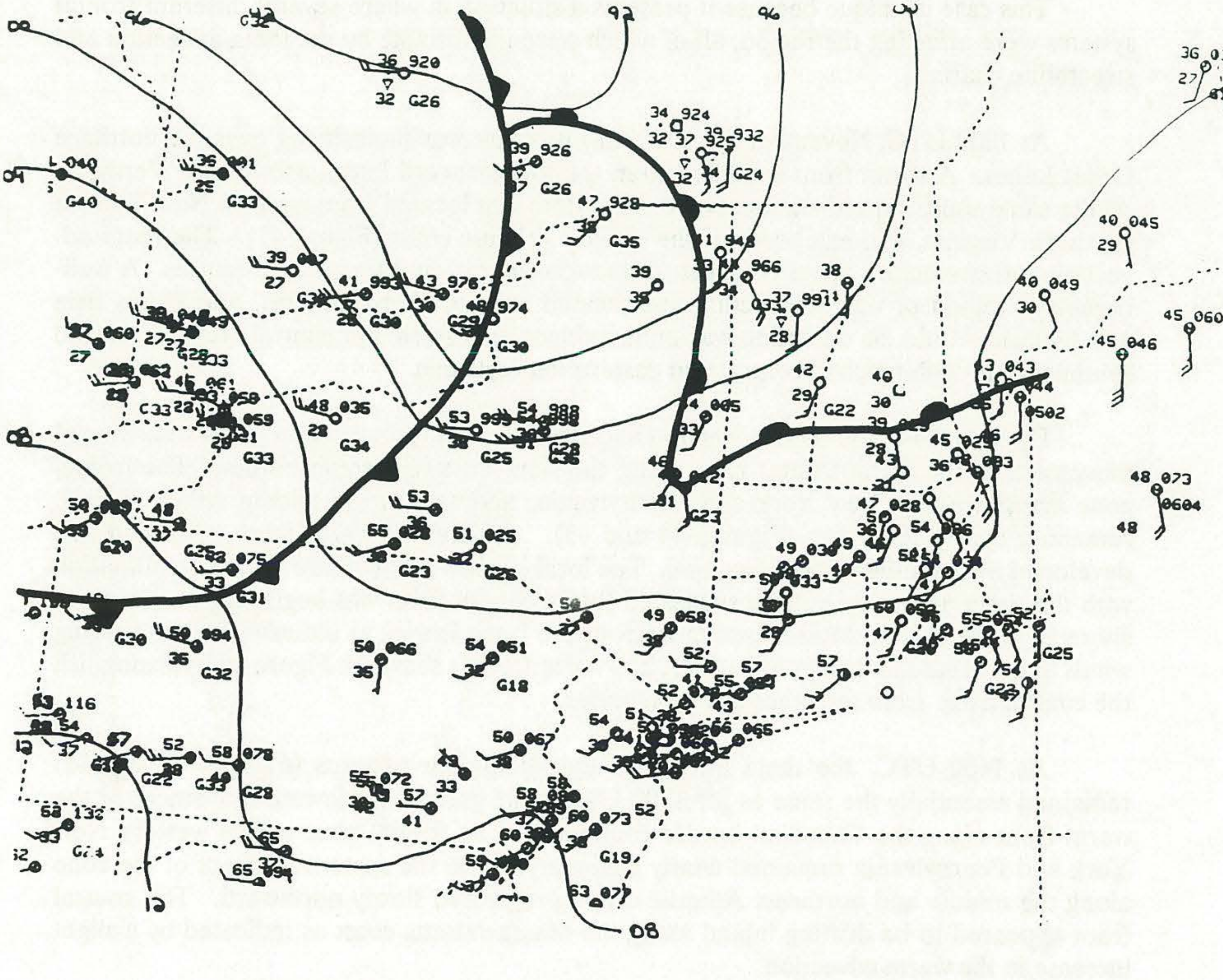

Figure 40. Surface plot and analysis for 1600 UTC, November 11, 1990.

4.4. CASE IV - MULTIPLE WARM AND QUASI-STATIONARY FRONTS

This case is unique because it presents a situation in where several different frontal systems were affecting the region, all of which were identifiable by the theta advection and streamline charts.

At 1000 UTC, November 27, 1990, low pressure was intensifying over the northern Great Lakes. A warm front extended from the low eastward into northwestern Vermont. At the same time, a quasi-stationary frontal system was located from western New York to northern Virginia, and extended off the middle Atlantic coast (Figure 41). The theta advection and streamline charts (Figures 42 and 43) clearly identified these features. A well-organized region of warm advection was located over southern Ontario, and Lakes Erie and Ontario. Cold air damming was quite evident in eastern and central New York, and southward through much of central and eastern Pennsylvania.

By 1200 UTC, the theta advection and streamline output displayed a slow northward movement of the warm frontal zone along the New York/Canadian border. The frontal zone across western New York and Pennsylvania, and east to the middle Atlantic coast, remained nearly stationary (Figures 44 and 45). An area of warm theta advection had developed over southeast New England. The local surface plot (Figure 46), in combination with the theta advection output, suggested that a coastal front was beginning to move onshore from the eastern Massachusetts westward to Long Island, as indicated by the veering winds and increase in dew points. A dashed warm front is shown in Figure 46 to distinguish the coastal front from the other frontal features.

At 1400 UTC, the theta advection and streamline patterns (Figures 47 and 48) remained essentially the same as for 1200 UTC. The gradual northward movement of the warm front along the Canadian border continued. The frontal zone across western New York and Pennsylvania remained nearly stationary, while the eastern segment of the zone along the middle and northeast Atlantic coasts progressed slowly northward. The coastal front appeared to be drifting inland along the Massachusetts coast as indicated by a slight increase in the warm advection.

By 1600 UTC, the warm front along the Canadian border had made little further progress into southern Canada. The frontal zone from western New York to the middle Atlantic coast continued to remain nearly stationary, although some weakening in the strength of the cold advection was evident. Meanwhile, the coastal front continued its slow drift inland (Figures 49-51).

At 1800 UTC, the gradual northward movement of the warm front in southern Canada persisted. Theta advection and streamline output (Figures 52 and 53) showed that some eastward progression of the frontal zone over central New York and Pennsylvania was occurring as the cold advection continued to weaken. The eastern (east-west) segment of this frontal zone remained stationary, as suggested in both the theta advection and streamline analyses. Warm advection continued to spread inland across coastal southern New England, with a corresponding northwest movement of the coastal front (Figure 54).

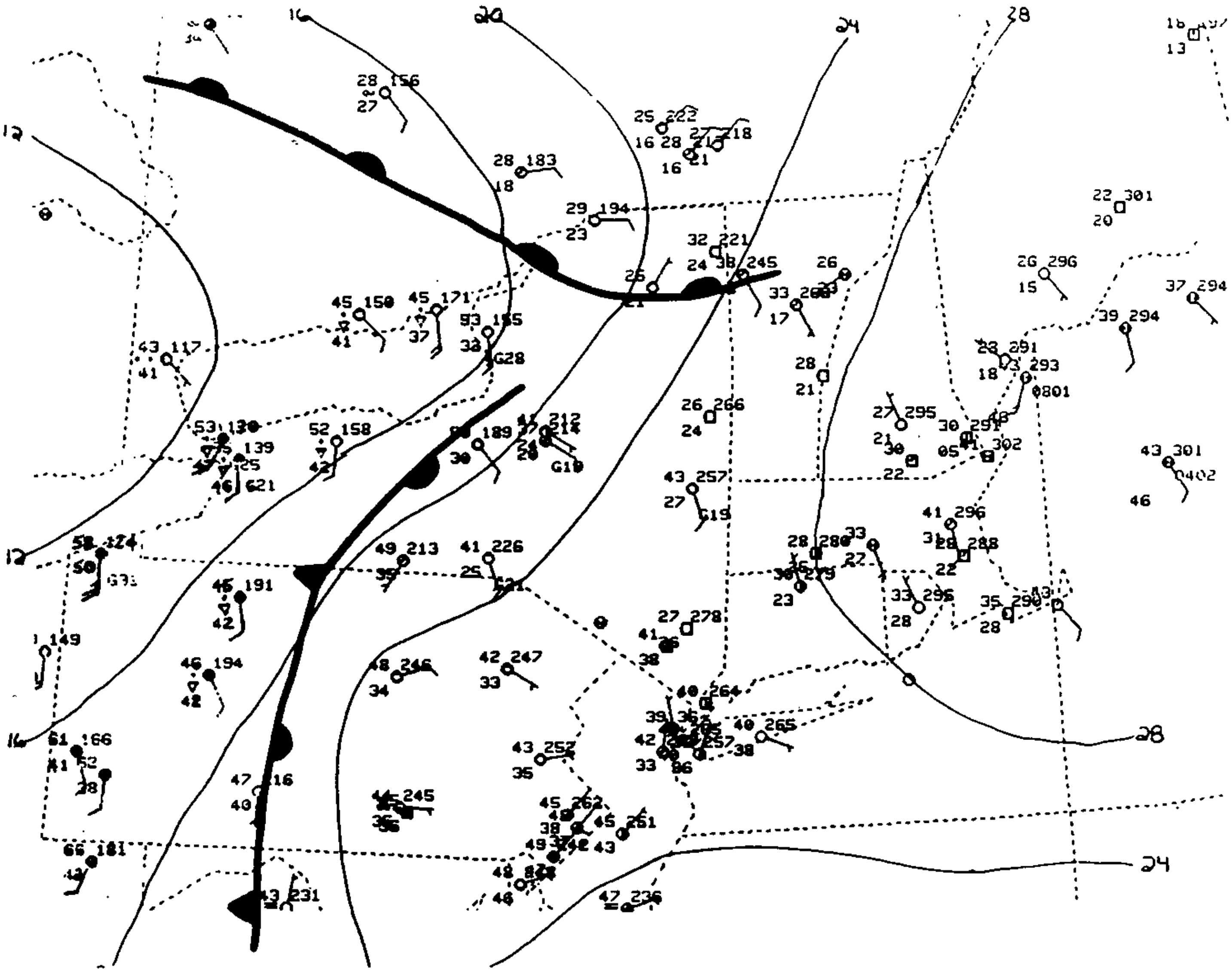

Figure 41. Surface plot and analysis for 1000 UTC, November 27, 1990.

Figure 42. Surface theta advection for 1000 UTC, November 27, 1990.

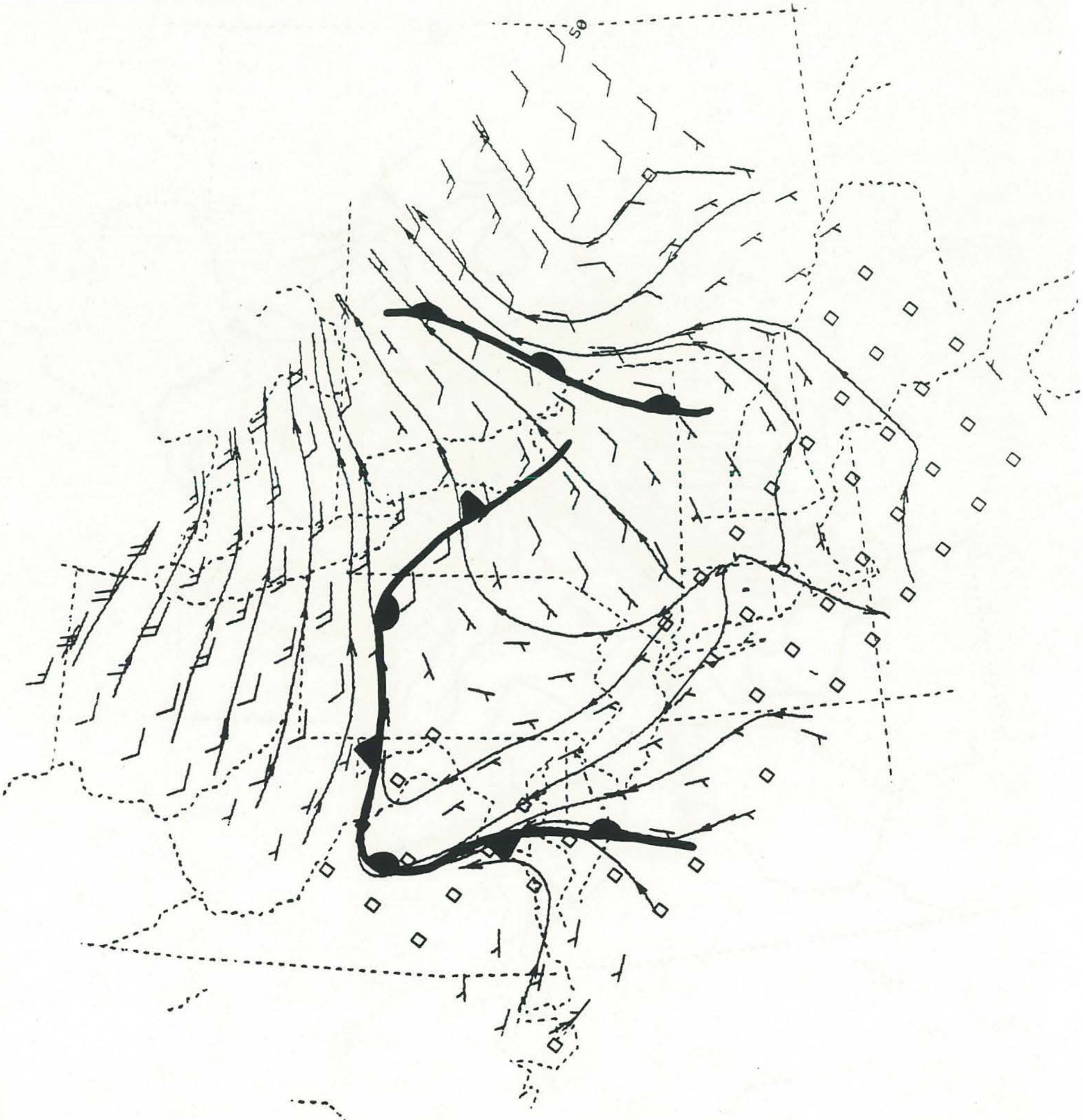

Figure 43. Surface streamlines/wind plot for 1000 UTC, November 27, 1990.

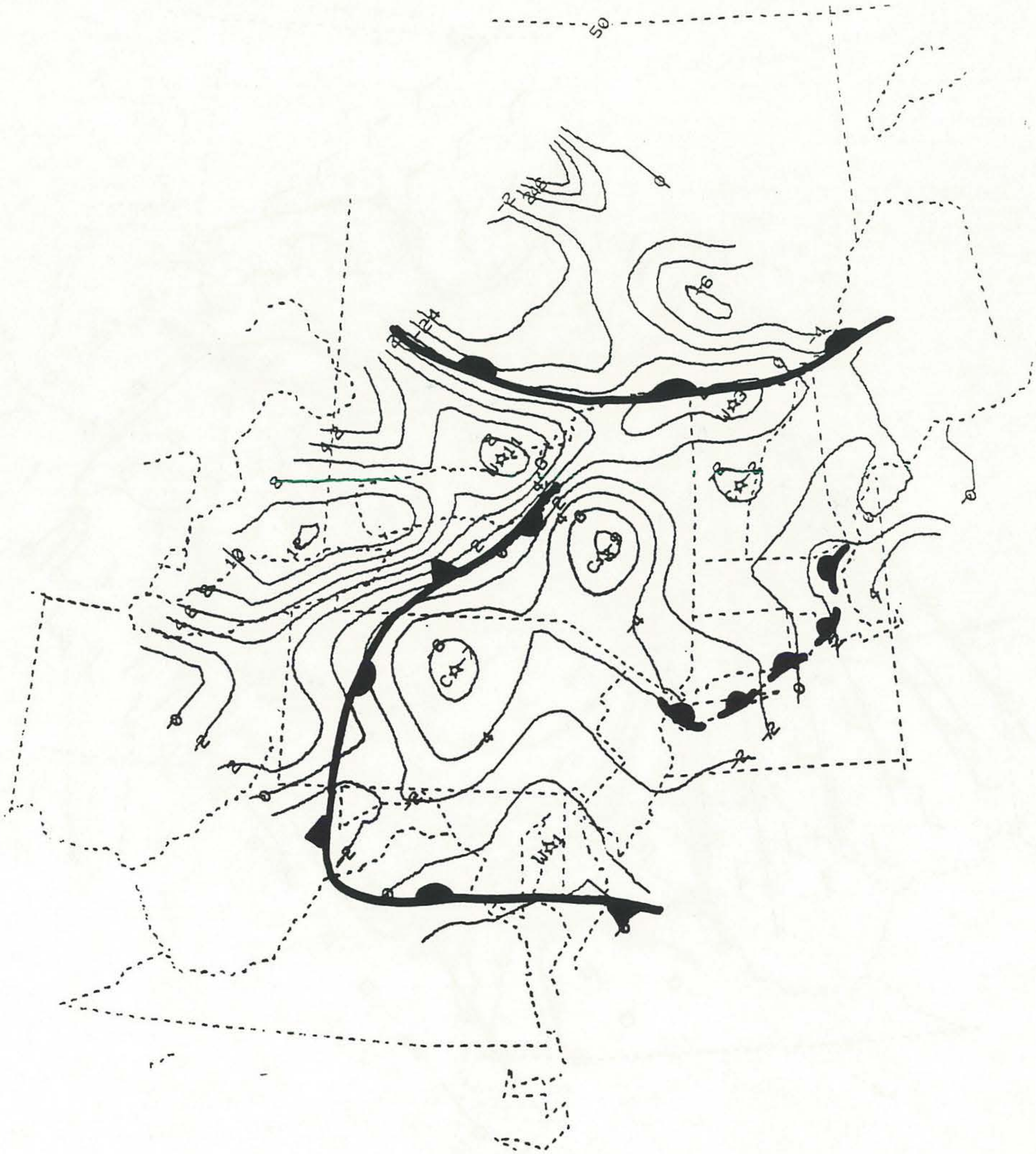

Figure 44. Surface theta advection for 1200 UTC, November 27, 1990.

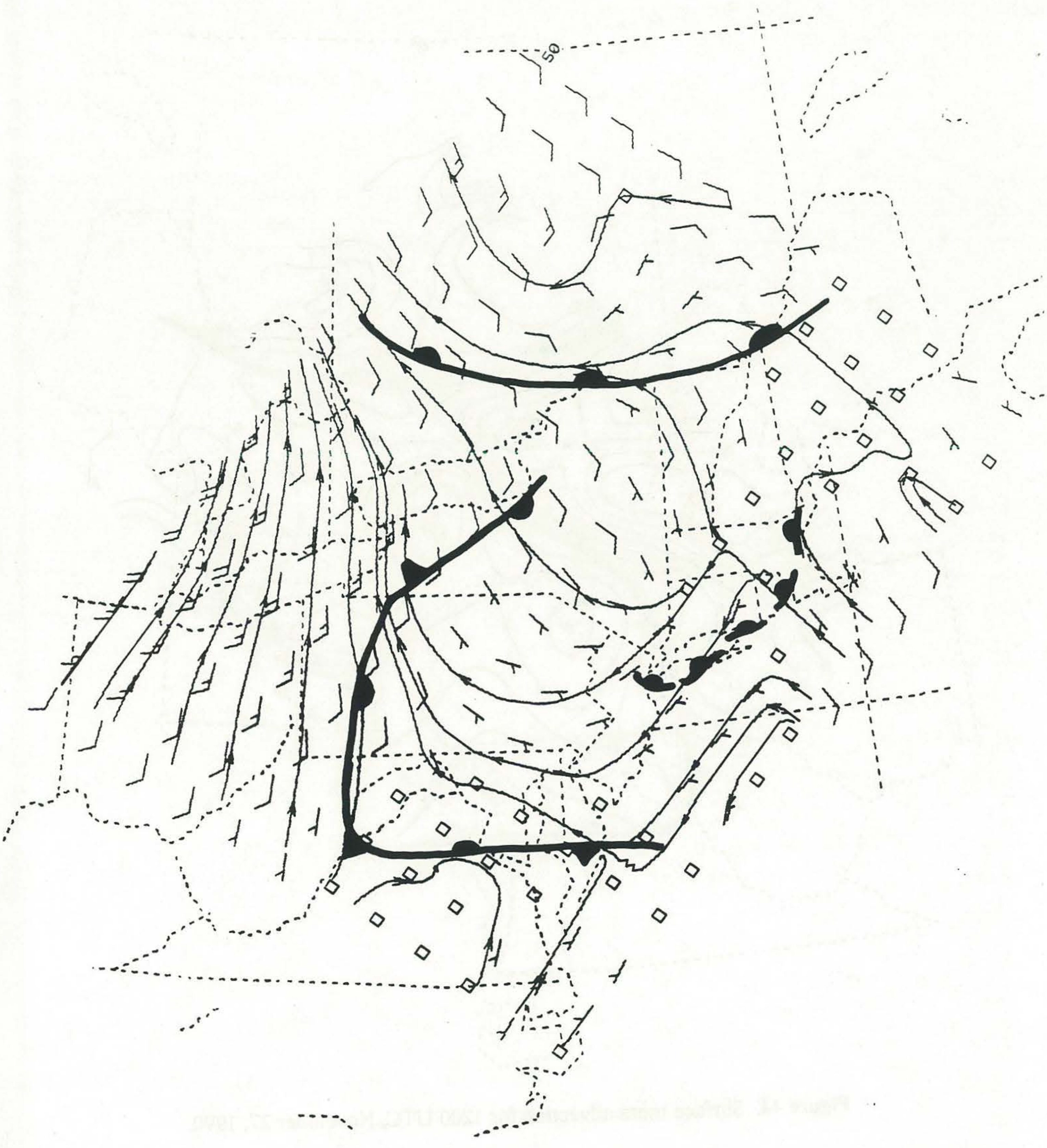

Figure 45. Surface streamlines/wind plot for 1200 UTC, November 27, 1990.

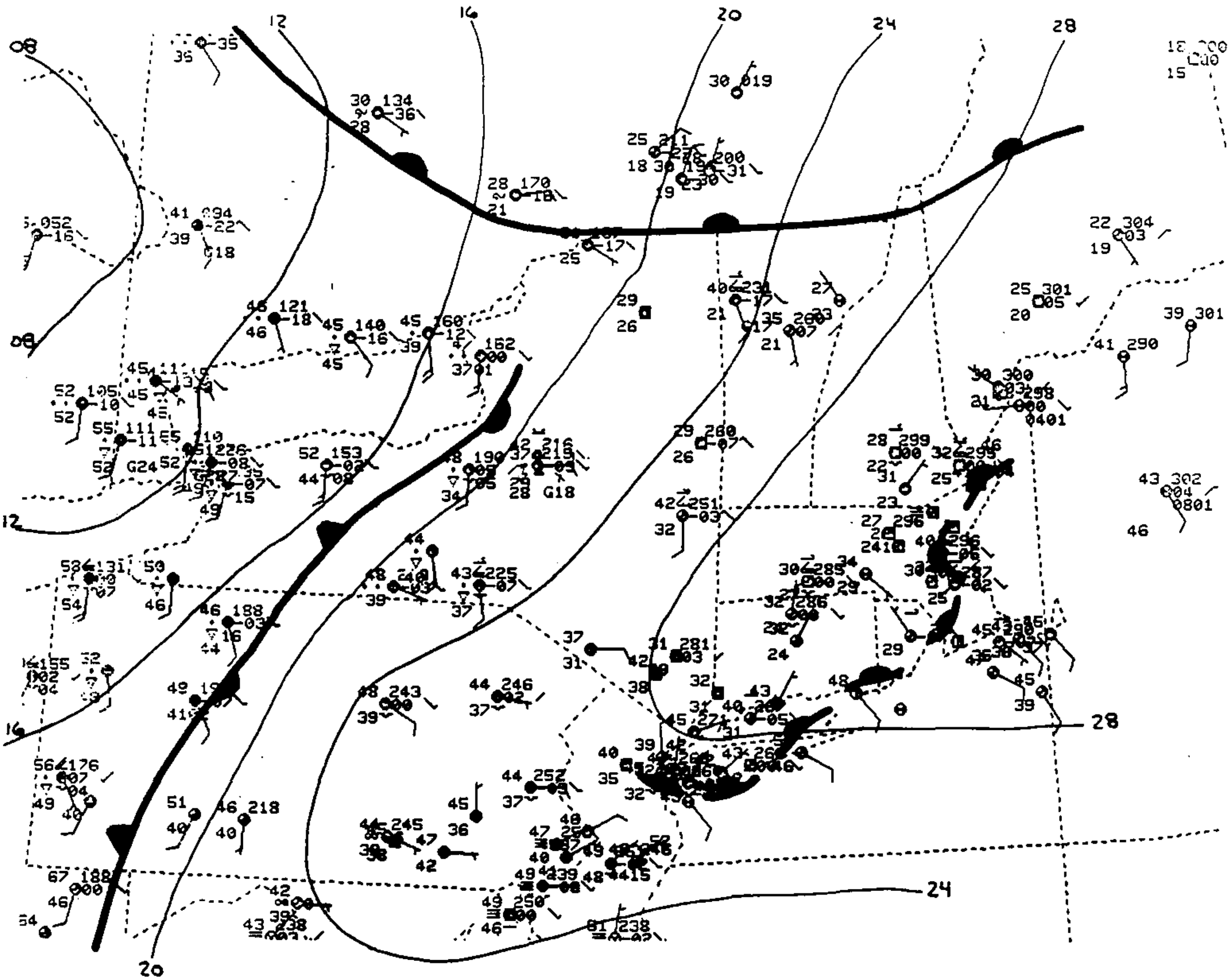

Figure 46. Surface plot and analysis for 1200 UTC, November 27, 1990.

Figure 47. Surface theta advection for 1400 UTC, November 27, 1990.

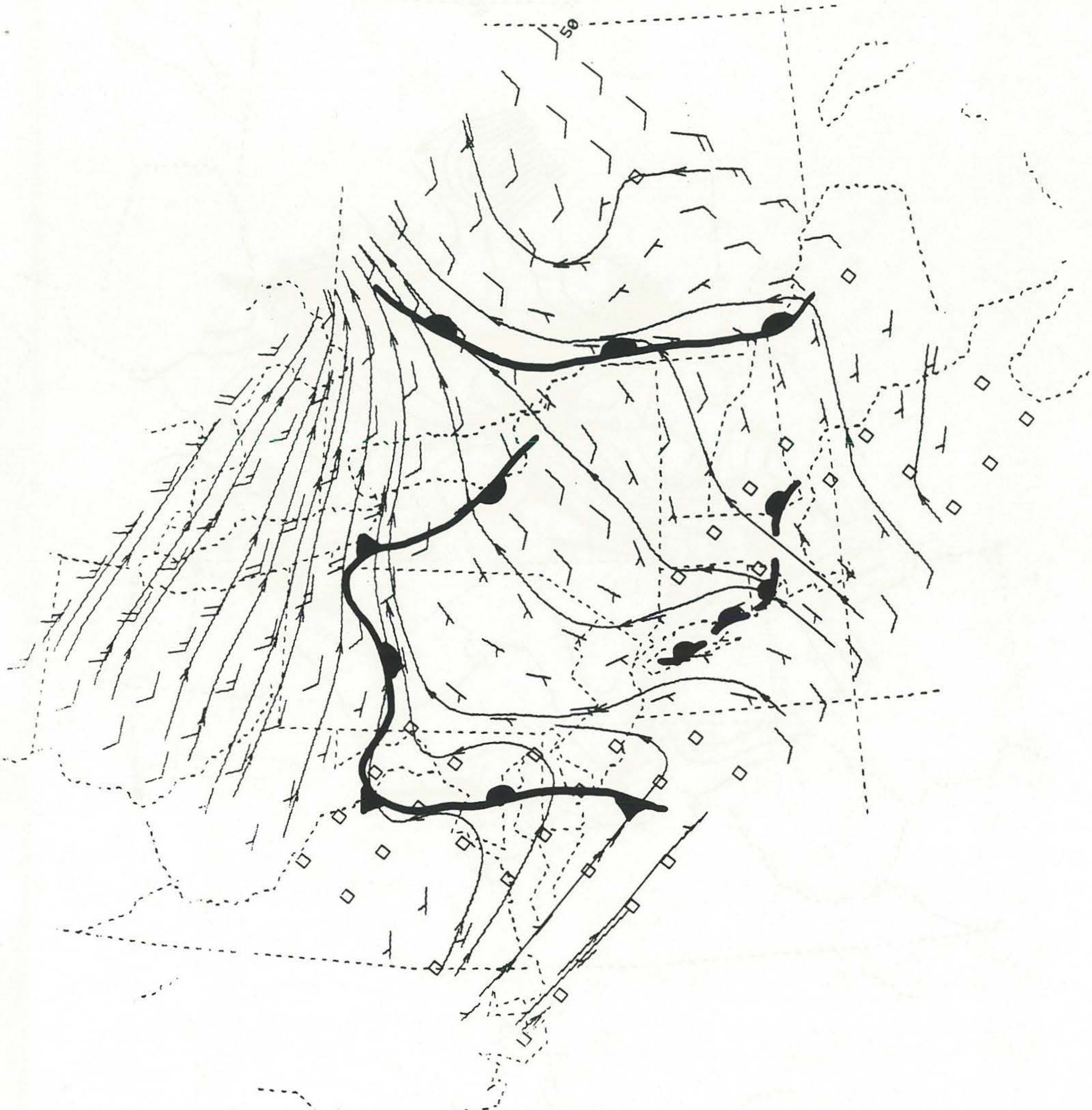

Figure 48. Surface streamlines/wind plot for 1400 UTC, November 27, 1990.

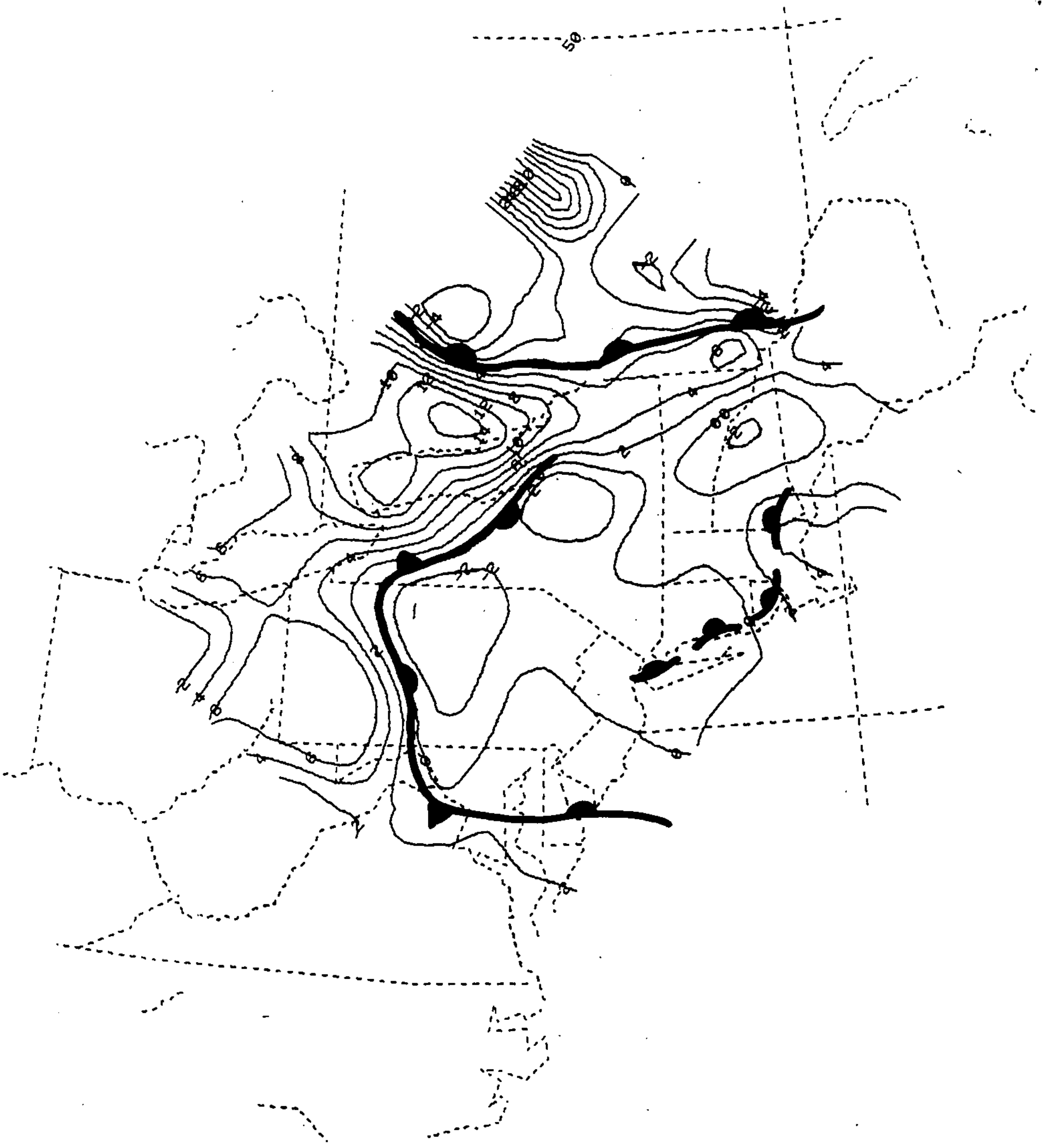

Figure 49. Surface theta advection for 1600 UTC, November 27, 1990.

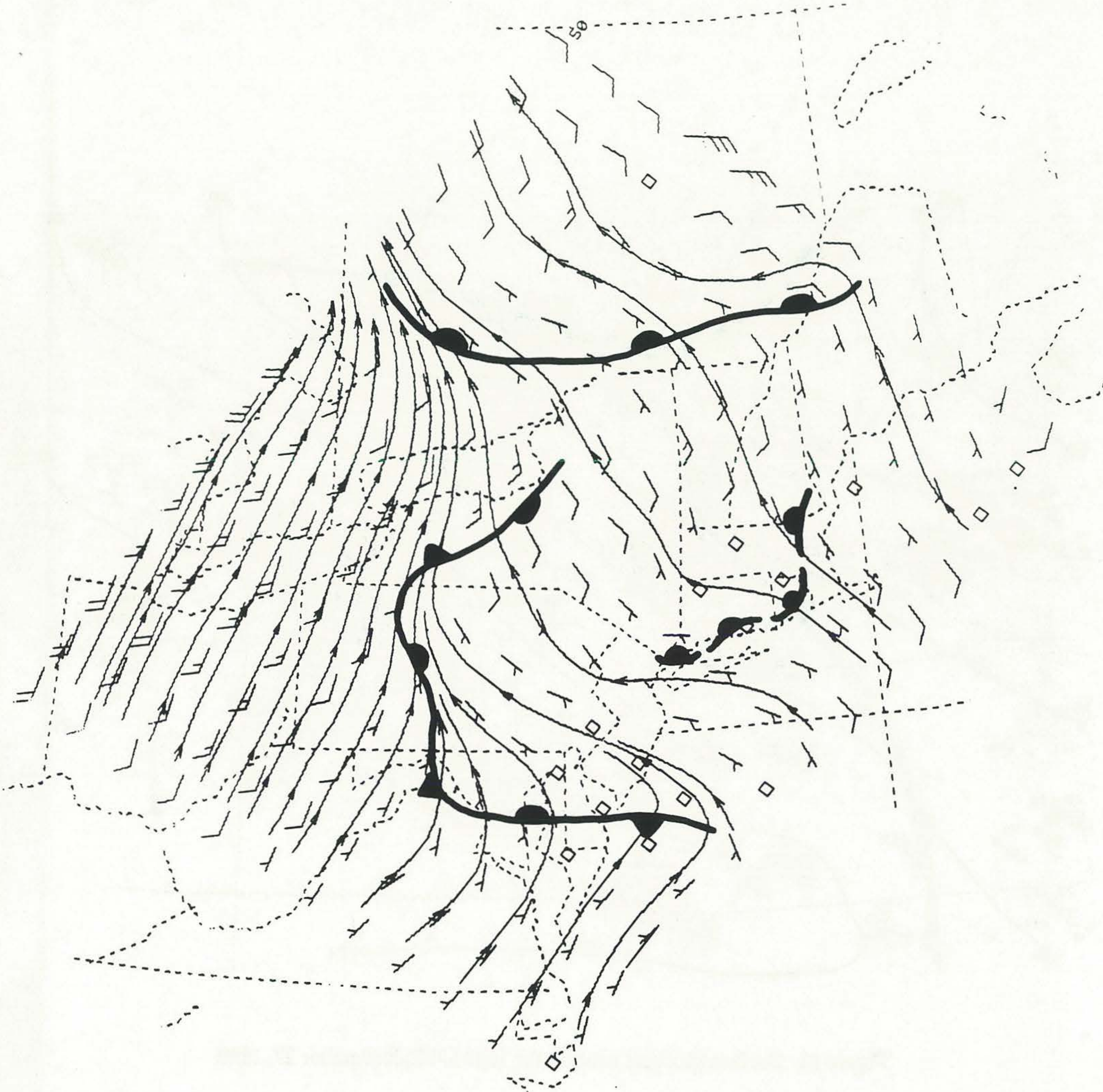

Figure 50. Surface streamlines/wind plot for 1600 UTC, November 27, 1990.

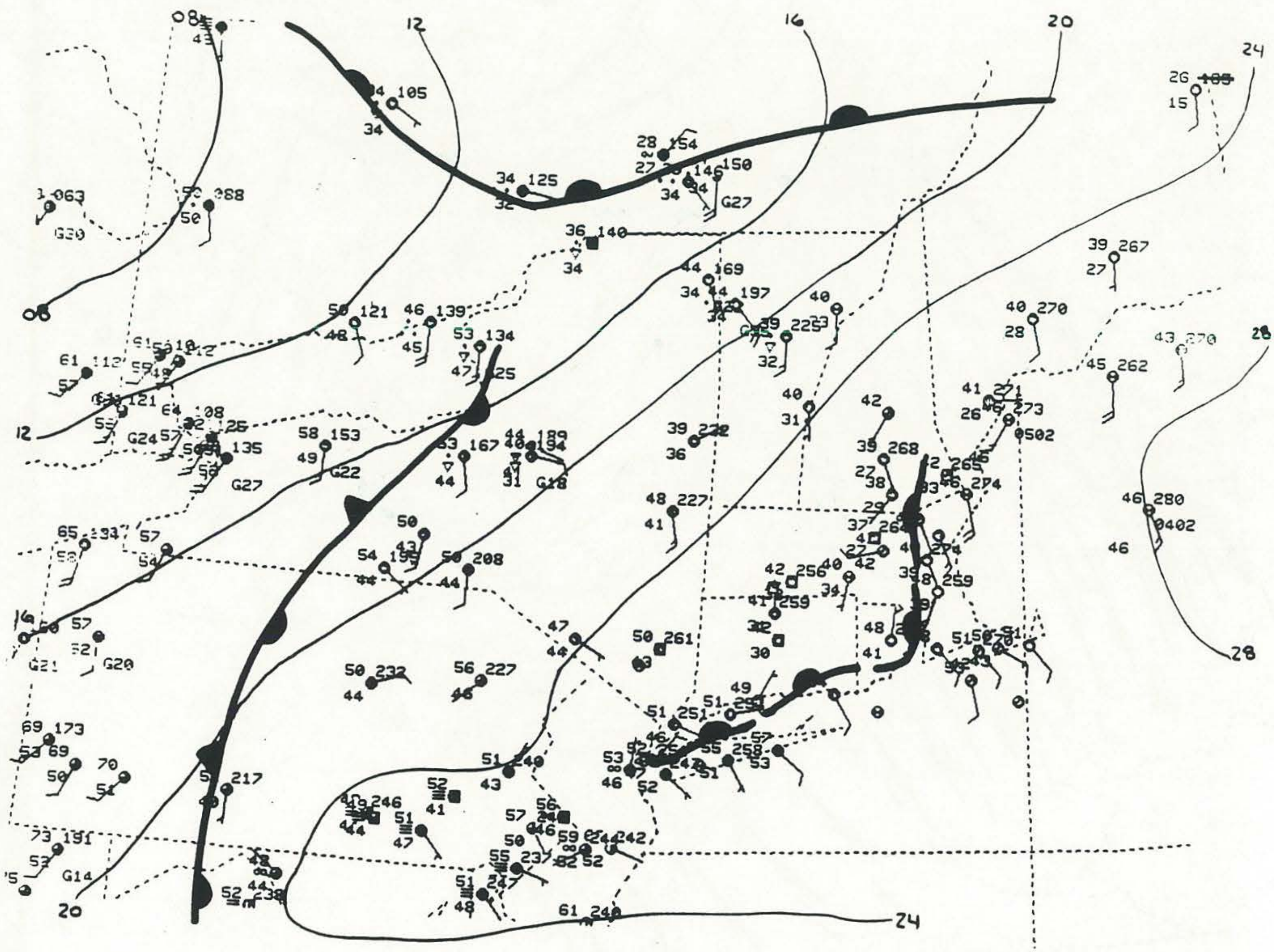

Figure 51. Surface plot and analysis for 1600 UTC, November 27, 1990.

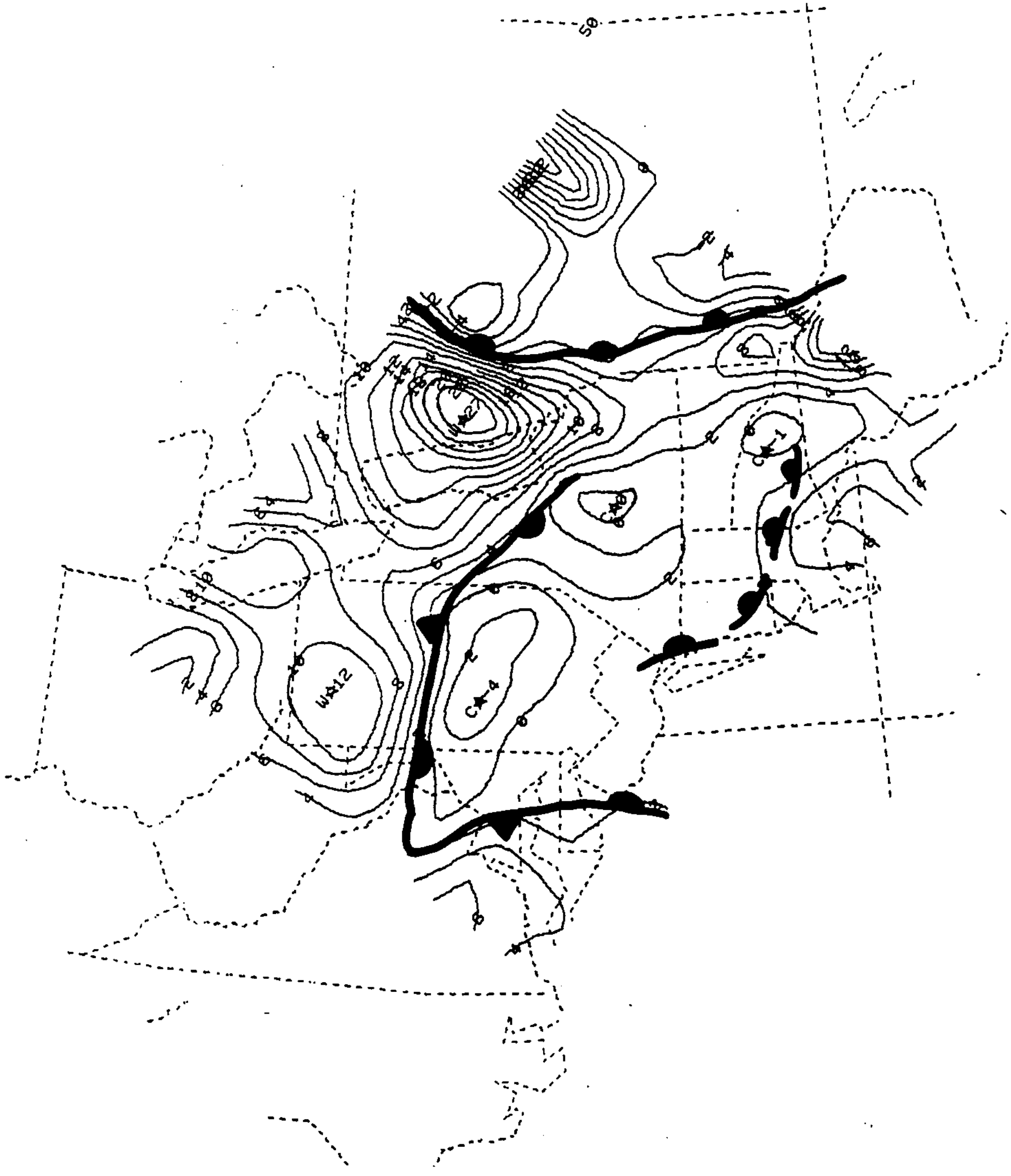

Figure 52. Surface theta advection for 1800 UTC, November 27, 1990.

Figure 53. Surface streamlines/wind plot for 1800 UTC, November 27, 1990.

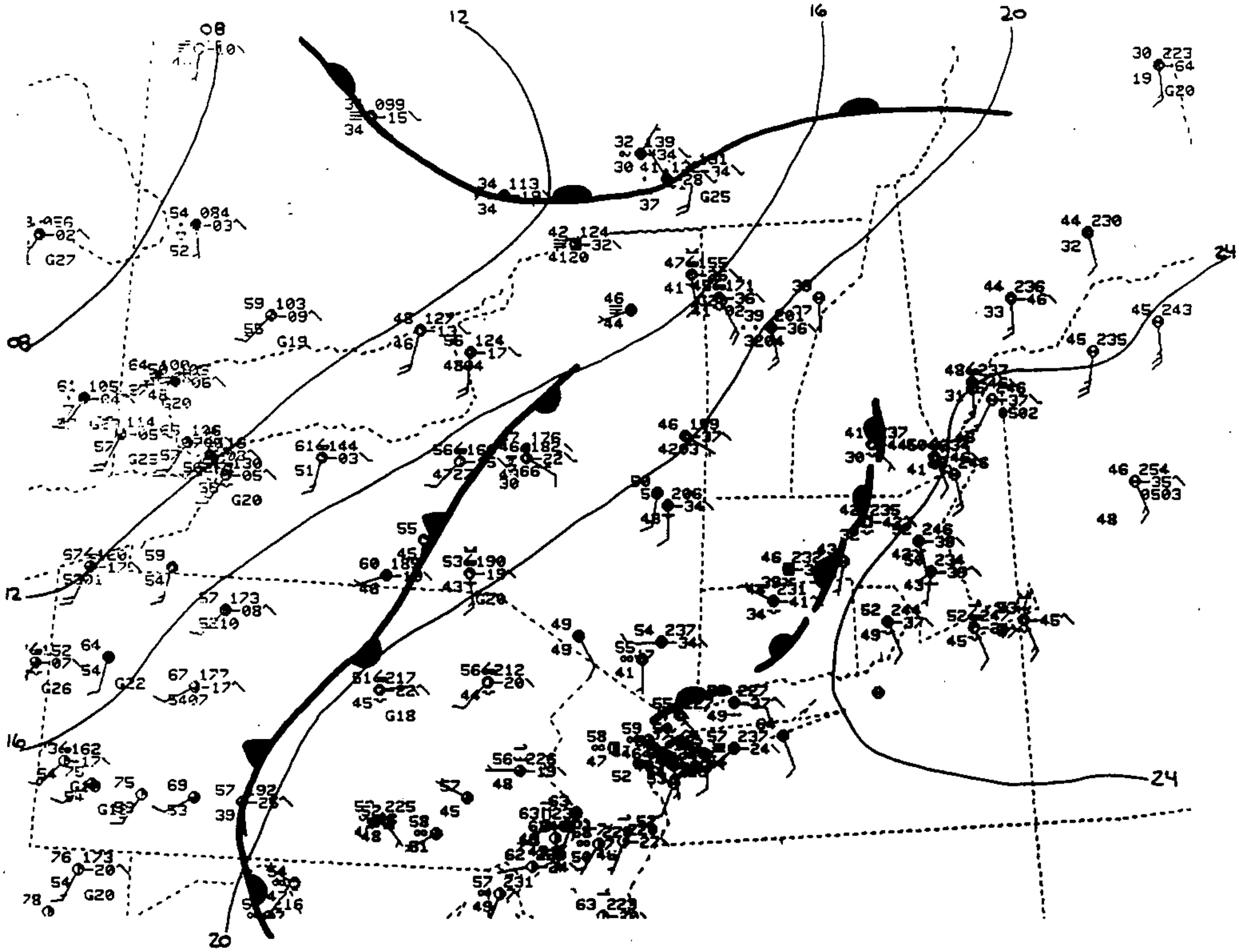

Figure 54. Surface plot and analysis for 1800 UTC, November 27, 1990.

4.5. CASE V - DEVELOPING WAVE ON A FRONT

This final case, although covering only a 2-hour period, was included for the purpose of providing an example of ADAP output during the formation of a weak frontal wave across southwest New England.

At 0300 UTC, May 14, 1990, a weak low pressure center had developed in southwestern Massachusetts, as indicated in the local surface plot and streamline analysis (Figures 55 and 56). The theta advection output (Figure 57) showed a distinct frontal boundary, that was aligned with convergence in the wind field. A quasi-stationary front, extended from the developing low in extreme southwest Massachusetts into the Gulf of Maine, as indicated by an area of warm advection located across southern New England, with cold advection located just to the north across southwest Maine. A cold front trailed from the low into northern Virginia, with strong cold advection evident behind the front.

At 0400 UTC, the streamline and theta advection charts (Figures 58 and 59) revealed the eastward movement of the low toward central Massachusetts, and a corresponding movement of the cold front into western New Jersey. The frontal zone across southern New England remained nearly stationary. The warm center moved east off the Massachusetts coastline, while the cold center remained nearly stationary.

As shown here, ADAP output during cyclogenesis can be extremely beneficial, not only with the identification of the frontal zone, but with tracking the surface low. A determination of how quickly the warm advection had progressed northward ahead of the low, and how rapidly cold advection had moved in behind the surface front could be made. In this case, little northward progress of the warm air ahead of the frontal wave was evident, while the cold advection appeared to be driving the cold front south and east.

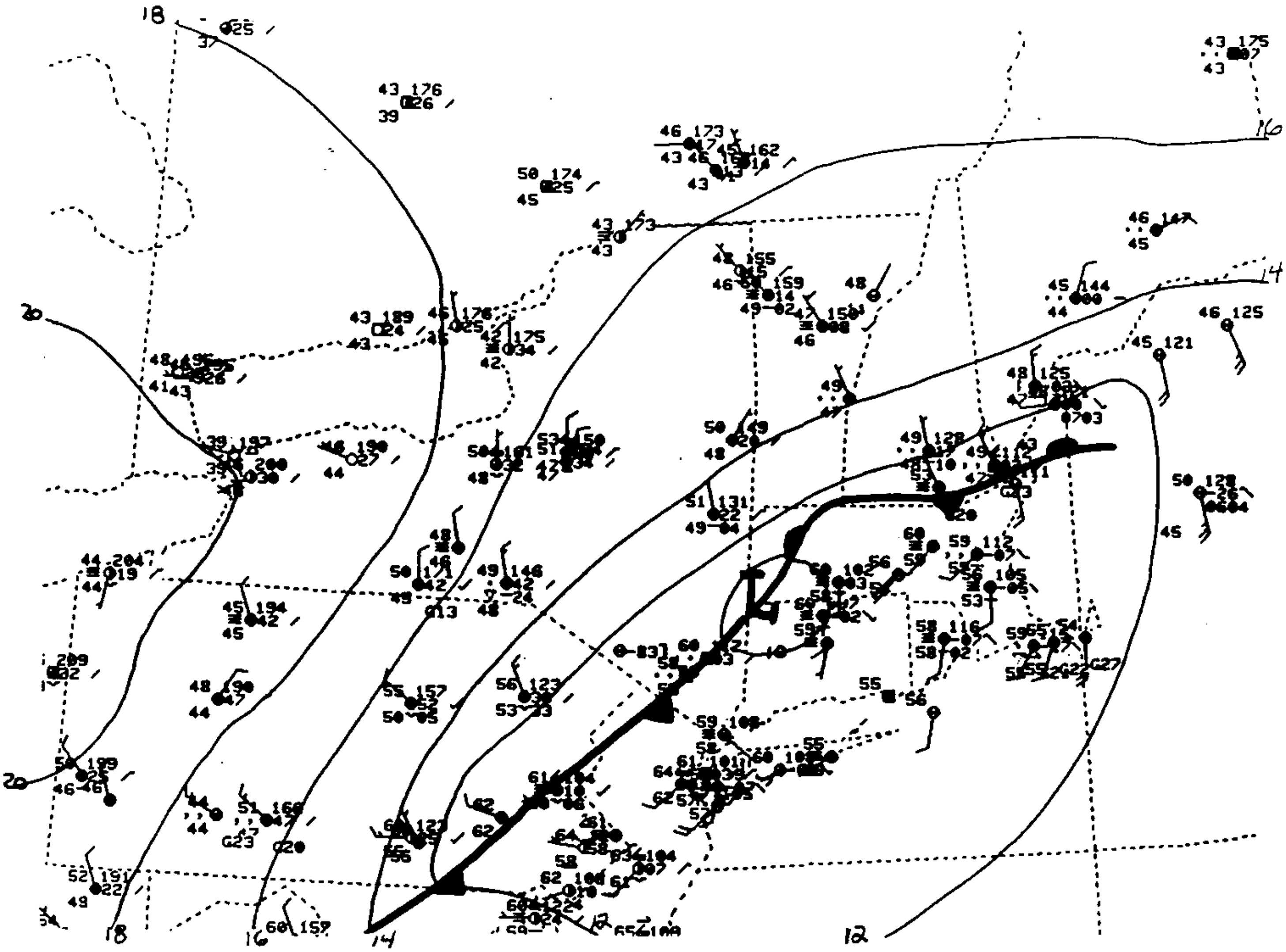

Figure 55. Surface plot and analysis for 0300 UTC, May 14 1990.

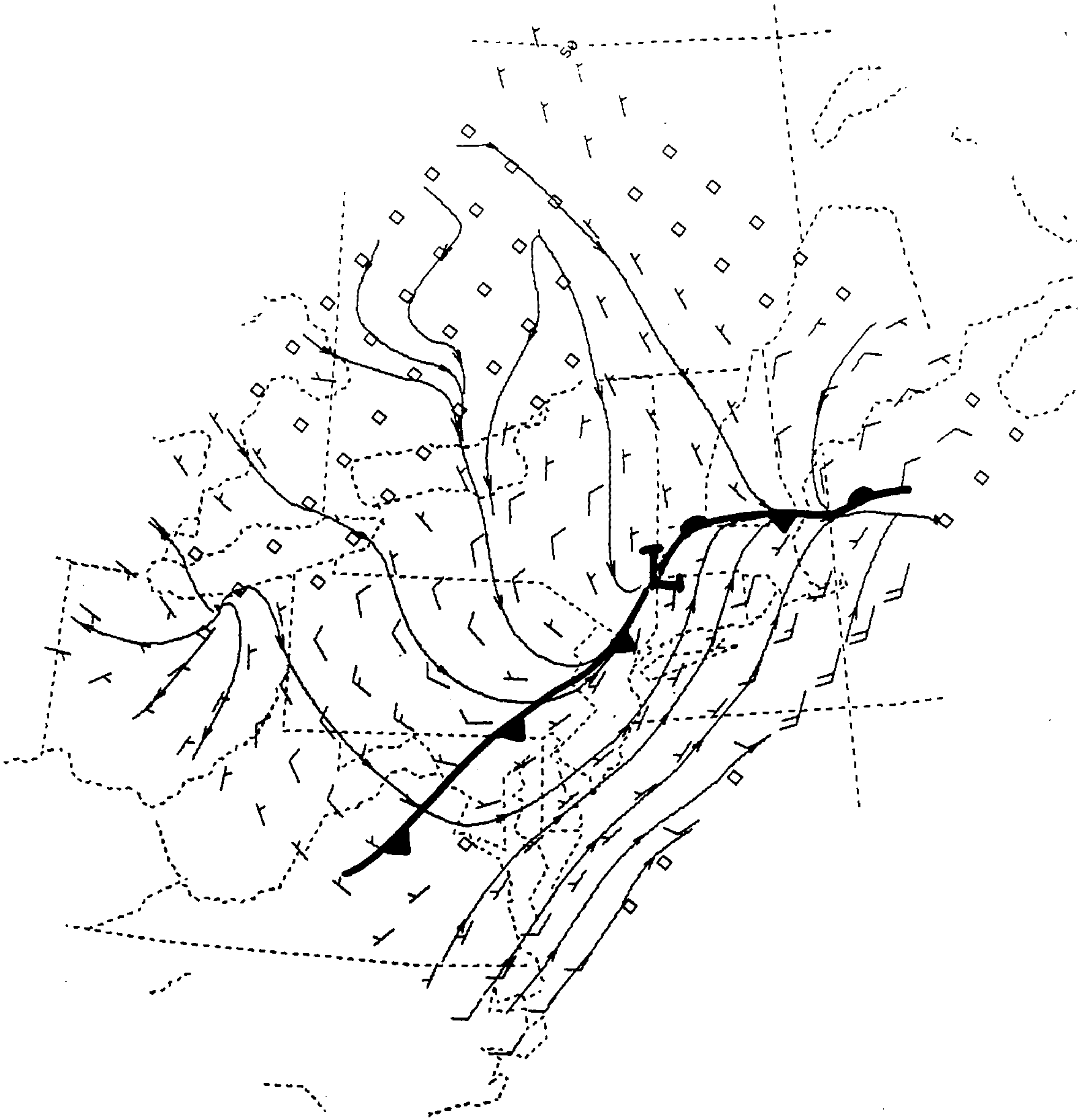

Figure 56. Surface streamlines/wind plot for 0300 UTC, May 14 1990.

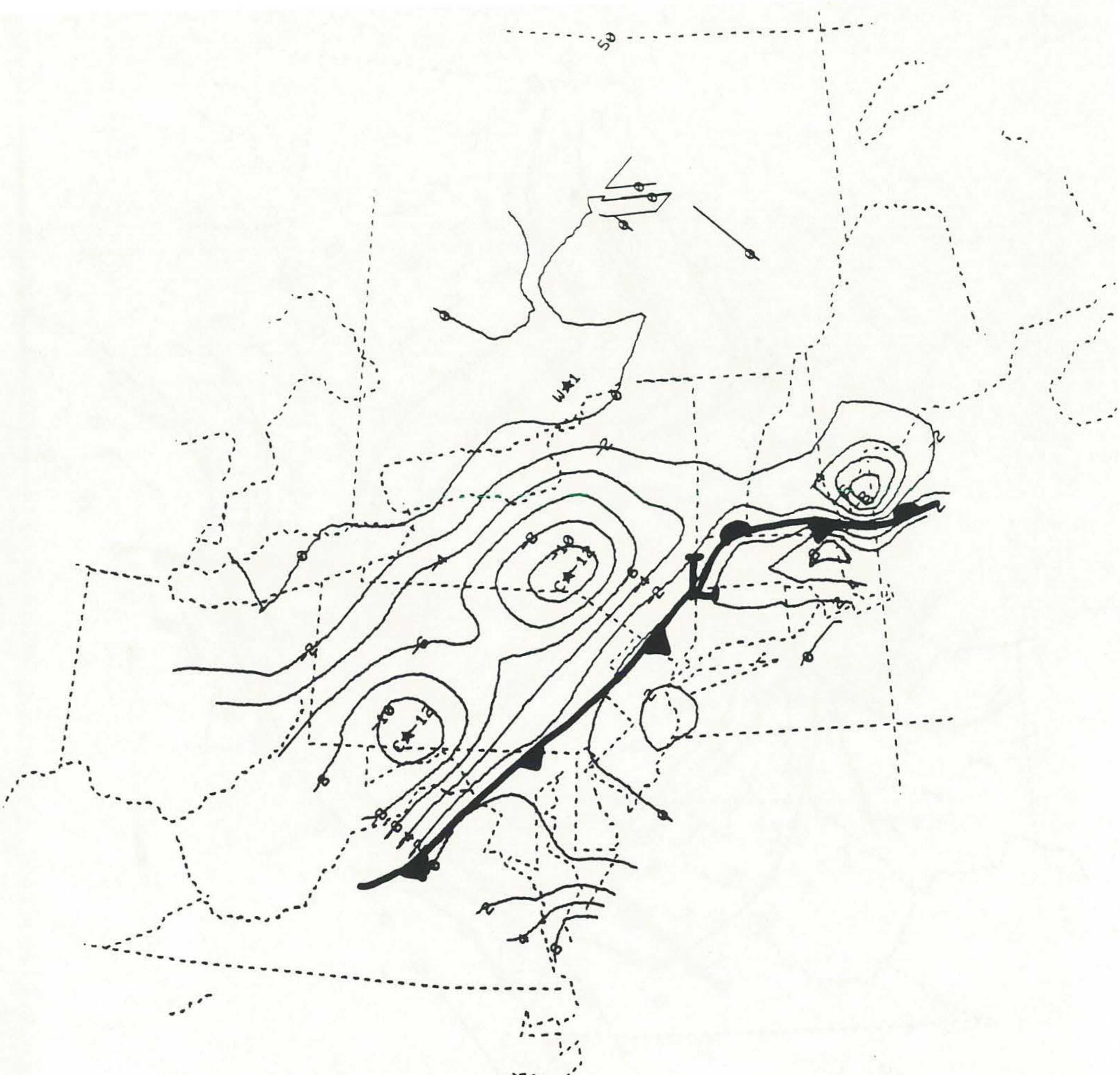

Figure 57. Surface theta advection for 0300 UTC, May 14 1990.

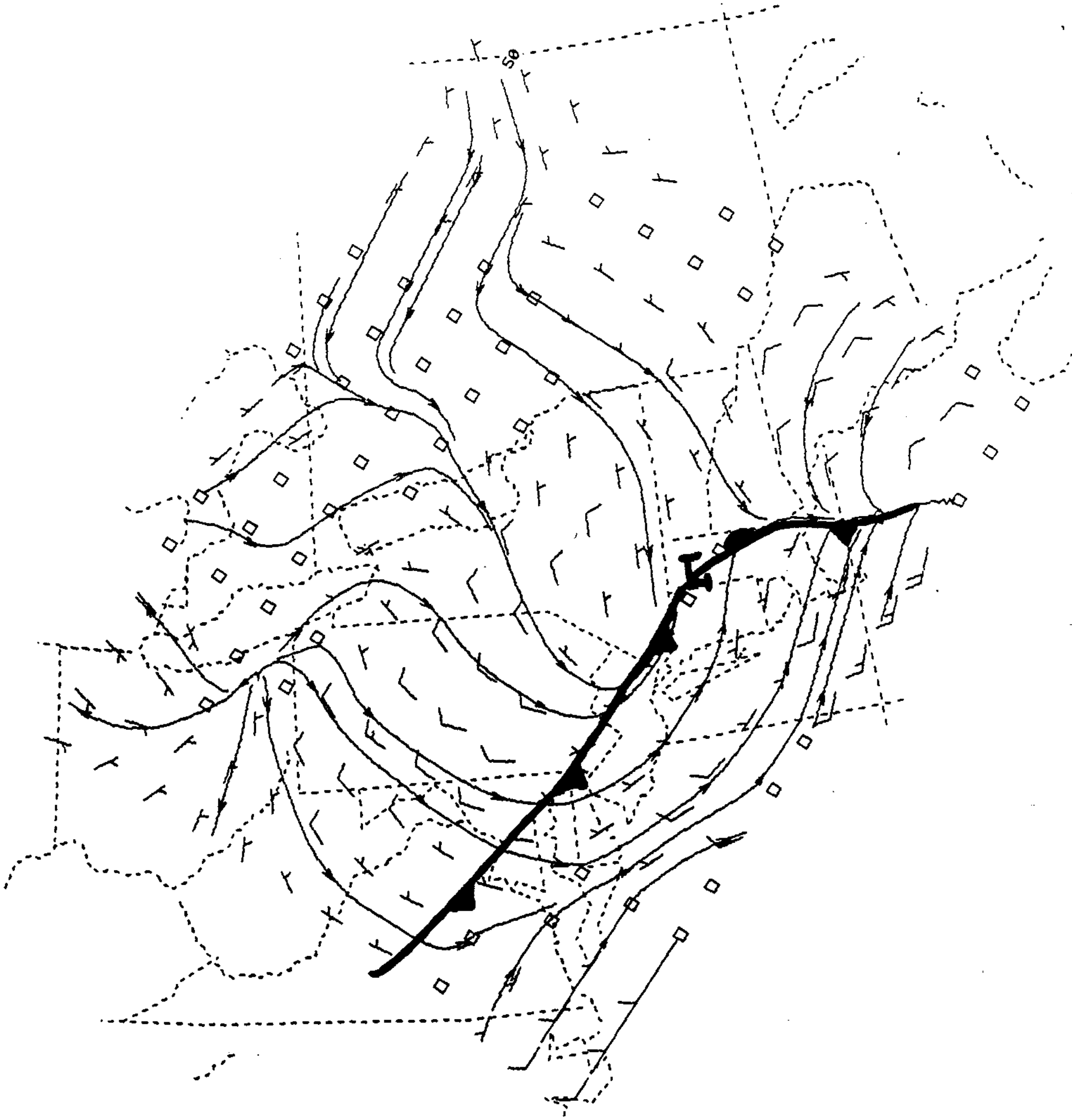

Figure 58. Surface streamlines/wind plot for 0400 UTC, May 14 1990

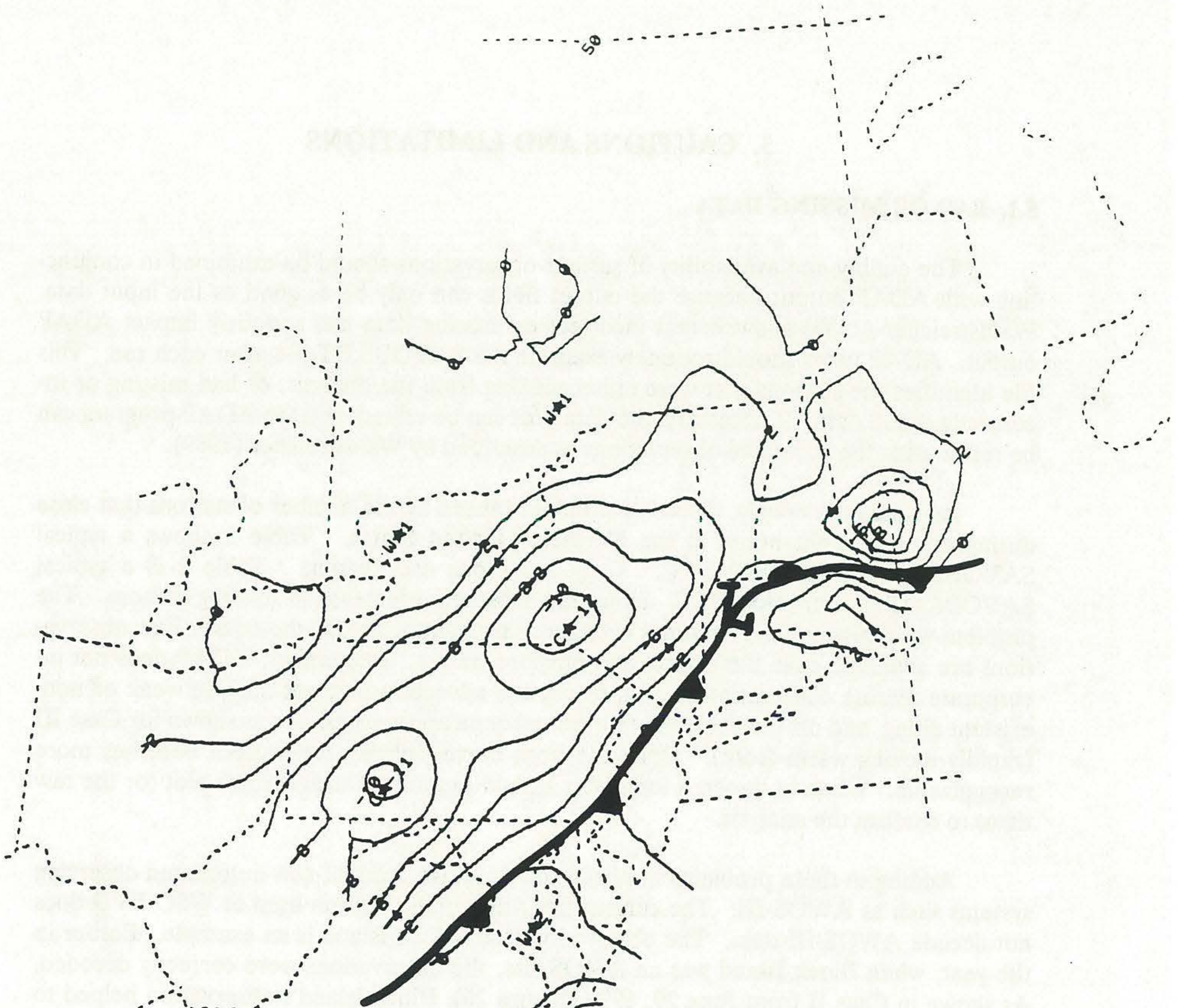

Figure 59. Surface theta advection for 0400 UTC, May 14 1990.

5. CAUTIONS AND LIMITATIONS

5.1. BAD OR MISSING DATA

The quality and availability of surface observations should be examined in conjunction with ADAP output because the output fields can only be as good as the input data. Waldstreicher (1989) showed that incorrect or missing data can seriously impact ADAP output. ADAP users should routinely examine the SAVOBS.DT file after each run. This file identifies the stations that were either missing from the analysis, or had missing or incorrectly coded data. If necessary, the data files can be edited, and the ADAP program can be rerun using the corrected observations as described by Waldstreicher (1989).

As stated previously, there is a problem caused by the number of stations that close during the late night hours in the Northeast United States. Table 1 shows a typical SAVOBS.DT file for 1800 UTC. Only 3 stations are missing. Table 2 is a typical SAVOBS.DT file for 0400 UTC. Note, the substantial increase in missing stations. The problem with missing data becomes even more pronounced along the coast. Few observations are available over the coastal and offshore waters. Remember, ADAP does not incorporate marine observations. As a result, the advection patterns may be weak or nonexistent along, and off the coastline as a frontal zone approaches, as was shown for Case III (rapidly moving warm front). Once the front moves inland, the pattern becomes more recognizable. When in doubt, a forecaster should examine a local surface plot (or the raw data) to confirm the analysis.

Adding to these problems has been the commissioning of new automated observing systems such as AWOS-III. The current SAO decoding program used at WSO PVD does not decode AWOS-III data. The observation from Block Island is an example. Earlier in the year, when Block Island was an AMOS site, the observations were correctly decoded. As shown in Case II from June 29, 1990 (Figure 26), Block Island's observation helped to identify the proximity of the frontal zone to the New England coast. In the late summer of 1990, AWOS-III was commissioned. As a result, these data are no longer available, as shown in Case III from November 11, 1990 (Figure 29). This problem will become a more common occurrence in the short term as additional AWOS-III sites are commissioned. An updated version of the SAO decoder program, which can properly decode the AWOS-III observation, is currently being tested. Until this new version is distributed to the field, however, forecasters should keep this problem in mind when examining ADAP output.

```
              SAO CHECK LIST FOR FILE SA18Z.DT
CHECK FOLLOWING STATION FOR ERROR IN DATA
STATION MGW  MISSING
STATION 3B1  MISSING
STATION YSJ  MISSING
END
```

TABLE 1. Example of a daytime SAVOBS.DT file:

```
              SAO CHECK LIST FOR FILE SA04Z.DT
CHECK FOLLOWING STATION FOR ERROR IN DATA
MSV  PP=-99 TT= -99 TD= -99 DD=   25 VV=  05 GG=  -9 AL=  -99
STATION MSV  MISSING
STATION UCA  MISSING
STATION ACK  MISSING
STATION BDR  MISSING
STATION JHW  MISSING
STATION EKN  MISSING
STATION MIV  MISSING
STATION DUJ  MISSING
STATION FKL  MISSING
STATION 3B1  MISSING
STATION CAR  MISSING
STATION ECG  MISSING
STATION RWI  MISSING
STATION LOZ  MISSING
STATION DAN  MISSING
STATION ROA  MISSING
STATION WOH  MISSING
STATION YSC  MISSING
STATION YUL  MISSING
STATION YHM  MISSING
STATION YPQ  MISSING
STATION YQA  MISSING
STATION YXR  MISSING
STATION YZR  MISSING
END
```

TABLE 2. Example of an early morning SAVOBS.DT file:

5.2. UNREPRESENTATIVE DATA

ADAP was designed to be sensitive to changes in the hourly data. These changes, however, can, at times, result in rather suspicious looking analyses. ADAP will check for missing data, or missing elements in an observation, but it will not discard existing values because they are not "in-line" with neighboring observations. As Doswell (1982) stated: "It is best to err on the side of retention. Spatial and temporal "smoothing" techniques within the program attempt to mitigate this potential problem. Some of the cases reviewed here presented suspicious looking areas in the theta advection patterns. Many of these areas were used to identify where future frontal movement was most likely to occur. This, however, might not always be the case. It is up to the forecasters to identify and isolate these features, and to determine whether or not to accept or reject the ADAP solution. This is why it is necessary to routinely examine and evaluate the data input to the program. In some cases, it may be necessary to examine the observations in considerable detail before drawing final conclusions.

6. CONCLUSIONS

ADAP charts of streamlines and theta advection can assist forecasters in quickly locating warm and quasi-stationary frontal systems. For the cases examined, the frontal boundary lined up well with the leading edge of the gradient of warm theta advection, that on occasion, corresponded with convergence and wind shift boundaries depicted in the streamline analyses. The theta advection fields also aided with the identification of cold air damming. Furthermore, the theta advection analyses detected areas of warm advection ahead of the frontal zone, as well as the erosion of cold air damming. Both features showed where future frontal movement was likely to occur.

ADAP is a powerful analysis and diagnostic tool. However, like any other forecast tool, it should never be used alone. Other data sources, such as satellite imagery, are also very useful in the identification of frontal boundaries. ADAP should be along side, rather than in place of, these other data sources.

Finally, ADAP output should never be viewed as a replacement for detailed hand analyses. Rather, it should be used in conjunction with them. Observations should be routinely checked for bad or missing data. Suspect areas should be identified and corrected, when necessary. If the ADAP output is used properly, increased accuracy in the location and short term movement of warm and quasi-stationary fronts should be the result.

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